NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

ORGANIZATIONAL CLIMATE AND ITS RELATIONSHIP WITH AVIATION MAINTENANCE SAFETY

by

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June 2001

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Form SF298 Citation Data

Report Date ("DD MON YYYY")	Report Type	Dates Covered (from... to) ("DD MON YYYY")
15 Jun 2001	N/A	

Title and Subtitle ORGANIZATIONAL CLIMATE AND ITS RELATIONSHIP WITH AVIATION MAINTENANCE SAFETY	**Contract or Grant Number**
	Program Element Number
Authors	**Project Number**
	Task Number
	Work Unit Number
Performing Organization Name(s) and Address(es) Naval Postgraduate School Monterey, CA 93943-5138	**Performing Organization Number(s)**
Sponsoring/Monitoring Agency Name(s) and Address(es)	**Monitoring Agency Acronym**
	Monitoring Agency Report Number(s)
Distribution/Availability Statement Approved for public release, distribution unlimited	
Supplementary Notes	
Abstract	
Subject Terms	
Document Classification unclassified	**Classification of SF298** unclassified
Classification of Abstract unclassified	**Limitation of Abstract** unlimited
Number of Pages 100	

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	June 2001	Master's Thesis

4. TITLE AND SUBTITLE
Organizational Climate and Its Relationship with Aviation Maintenance Safety

5. FUNDING NUMBERS

6. AUTHOR(S)
Hernandez, Alison E.

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Naval Postgraduate School
Monterey, CA 93943-5000

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Naval Safety Center and School of Aviation Safety

10. SPONSORING / MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES
The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(maximum 200 words)* Naval Aviation is continually looking for ways to reduce its mishap rate. Recognizing a growing concern for issues related to aging aircraft, focus has expanded to include maintenance operations. It is accepted that human error is a causal factor in at least eighty percent of all mishaps, with maintainer, line, or facility-related factors accounting for one out of five major mishaps. One of several actions taken to reduce the mishap rate is the Maintenance Climate Assessment Survey (MCAS). Created to give Naval Aviation unit commanding officers a sense of the maintenance climate of their unit, the MCAS reveals the maintainer's perception of safety climate. Beginning in July 2000, the MCAS administration became available via the Internet. This thesis analyzes the results of the first 2,180 responses recorded via the Internet version of MCAS. Findings include: a) administration of the Internet-based MCAS yields results similar to the paper-and-pencil version; b) differences were detected among the participating units and the Model of Organization Safety Effectiveness components; c) the relationship between MCAS score and Incident Rate, although slightly negative, is indistinguishable from random variation; d) there was no evidence that demographics bias the results. These findings could be accounted for by the fact that a unit's safety climate typically improves after a mishap. Requiring all units to complete the survey annually would allow tracking over time to uncover trends. One area for further research is investigating the feasibility of adapting the MCAS to afloat and ashore units.

14. SUBJECT TERMS
Safety Climate, Maintenance, Human Factors, Human Error, High Reliability Organizations, Safety Culture, Naval Aviation

15. NUMBER OF PAGES
100

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECRUITY CLASSIFICATION OF THIS PAGE	20. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL

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ORGANIZATIONAL CLIMATE AND ITS RELATIONSHIP WITH AVIATION MAINTENANCE SAFETY

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Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN OPERATIONS RESEARCH

from the

NAVAL POSTGRADUATE SCHOOL
June 2001

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ABSTRACT

Naval Aviation is continually looking for ways to reduce its mishap rate. Recognizing a growing concern for issues related to aging aircraft, focus has expanded to include maintenance operations. It is accepted that human error is a causal factor in at least eighty percent of all mishaps, with maintainer, line, or facility-related factors accounting for one out of five major mishaps. One of several actions taken to reduce the mishap rate is the Maintenance Climate Assessment Survey (MCAS). Created to give Naval Aviation unit commanding officers a sense of the maintenance climate of their unit, the MCAS reveals the maintainer's perception of safety climate. Beginning in July 2000, the MCAS administration became available via the Internet. This thesis analyzes the results of the first 2,180 responses recorded via the Internet version of MCAS. Findings include: a) administration of the Internet-based MCAS yields results similar to the paper-and-pencil version; b) differences were detected among the participating units and the Model of Organization Safety Effectiveness components; c) the relationship between MCAS score and Incident Rate, although slightly negative, is indistinguishable from random variation; and d) there was no evidence that demographics bias the results. These findings could be accounted for by the fact that a unit's safety climate typically improves after a mishap. Requiring all units to complete the survey annually would allow tracking over time to uncover trends. One area for further research is investigating the feasibility of adapting the MCAS to afloat and ashore units.

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LIST OF DEFINITIONS

The following definitions are used throughout this thesis:

Aircraft Ground Mishap (AGM). Those mishaps in which no "intent for flight" (intention to fly) existed at the time of the mishap and loss of an aircraft or $10,000 or more in damage to an aircraft or property occurred.

Flight Mishap (FM). Those mishaps in which there is $10,000 or greater aircraft damage or loss of aircraft with the existence of intent for flight for the aircraft at the time of the mishap.

Flight-Related Mishap (FRM). Those mishaps in which there is intent for flight at the time of the mishap and $10,000 or greater aircraft damage or loss of an aircraft, and/or property damage occurs.

High-Reliability Organization (HRO). An organization that operates in a hazardous environment, yet experiences few failures due to effective leadership, sound management policies, procedure standardization, adequacy of resources and staffing, and a defined system for risk management.

Human Factors Accident Classification System – Maintenance Extension (HFACS-ME). A taxonomic system used to classify causal factors that contribute to maintenance-related mishaps.

Incidence Rate. The total number of mishap reports or Hazard Reports per 100,000 flight hours.

Maintenance Climate Assessment Survey (MCAS). A 43-item survey used to gain insight into an aircraft maintainer's perception concerning maintenance operations and safety within the Navy and Marine Corps Aviation.

Maintenance-Related Incidents (MRIs)

Mishap. A Naval Aviation mishap is an unforeseen or unplanned event that directly involves naval aircraft and which results in $10,000 or greater cumulative damage to naval aircraft or personnel. Mishaps are further divided into three classes based on the amount of damage to the aircraft, property and personnel injury. Mishaps are documented as a mishap report (MR). The following are the definitions of the three classes:

a. Class A. A mishap in which the total cost of property damage (including all aircraft damage) is $1,000,000 or greater, or a naval aircraft is destroyed or missing, or any fatality or permanent total disability of a person occurs with direct involvement of Naval aircraft.

b. Class B. A mishap in which the total cost of property damage (including all aircraft damage) is $200,000 or more but less than $1,000,000 and/or a permanent partial disability, and/or the hospitalization of five or more personnel occurs.

c. Class C. A mishap in which the total cost of property damage (including all aircraft damage) is $10,000 or more but less than $200,000 and/or there is an injury resulting in one or more lost workdays.

Hazard An incident in which the total cost of property damage (including all aircraft damage) is less than $10,000 and no work days are lost to injury. Hazards are documented as a hazard report (HAZREP).

Naval Aircraft. Refers to U.S. Navy, U. S. Naval Reserve, U.S. Marine Corps, and U.S. Marine Corps Reserve aircraft.

EXECUTIVE SUMMARY

Naval Aviation is continually looking for ways to reduce its mishap rate. Recognizing a concern for issues related to aging aircraft, focus has expanded to include maintenance operations. It is accepted that human error is a causal factor in at least eighty percent of all mishaps, with maintainer, line, or facility-related factors accounting for one out of five major mishaps. The Human Factors Quality Management Board (HFQMB) was created in 1996 to specifically address human errors in FMs. During the first 18 months of its existence, "…the Navy FM rate dropped to its lowest point ever…" (Schmidt, Schmorrow, & Hardee,. 1998). Energized by these results and recognizing a concern for issues related to aging aircraft, the HFQMB decided to expand its focus to include maintenance operations (Schmidt *et al.* 1998).

To tackle human error in aviation maintenance the Naval Safety Center and the Naval Postgraduate (NPS) School of Aviation Safety created two tools to assess maintainer error, trends and other factors which contribute to an incident, including the unit's safety climate. The first tool is the Human Factors Analysis Classification System – Maintenance Extension (HFACS-ME) developed by Schmidt, Schmorrow, and Hardee (1998) that classifies causal factors contributing to maintenance-related incidents (MRIs). The second tool is the Maintenance Climate Assessment Survey (MCAS). Baker (1999) used a model of safety effectiveness based on research done on High-Reliability Organizations, the Model of Safety Effectiveness (MOSE) and the Command Safety Climate Survey to create a 35-item MCAS. Goodrum (1999), Oneto (1999), the School of Aviation Safety, and AIRPAC took the 35-item MCAS and developed a 43-item survey. Harris (2000) and Stanley (2000) took the 43-item survey and assisted in administering it to the 3rd Marine Air Wing. Harris found that no one MOSE area or question dominated the outcome of the survey and recommended changes to represent U. S. Marine Corps aviation units. Stanley determined that demographic factors account for minimal variance in the responses and concluded that the MCAS is demographically unbiased. In July 2000, the MCAS became available on-line for any Naval Aviation unit to take.

This study examines the on-line administration and tries to ascertain whether MCAS results differ between those units that have experienced recent maintenance-related incidents and those that have not. The study also examines demographic factors to determine if they are correlated with MCAS responses. With the study of 2,180 maintainer surveys from 30 Naval Aviation units, an attempt to assess the maintenance safety climate within each unit is made.

Principal component analysis does not identify any one MOSE component or question that was responsible for controlling the outcome of the survey. Analysis of Variance (ANOVA) and Multiple Comparison testing shows that the MCAS can detect differences between MOSE components and units' MCAS response. Linear Regression is performed using the MRI Rate as the dependent variable and the mean MCAS response as the independent variable. While the relationship between MCAS score and Incident Rate is slightly negative, it is indistinguishable from random variation. Component scores are fitted using demographics as the independent variables. The results show that demographic factors account for minimal variance and therefore the MCAS appears to be demographically unbiased. While these results are counter-intuitive, it may be that a unit's safety climate improves after it experiences a mishap.

ACKNOWLEDGEMENT

The author would like to acknowledge the members of her thesis committee for their assistance, guidance and patience throughout this process. In particular, to Professor Sam Buttrey for his patience and willingness to help not only her, but, every student that comes knocking at his door; to Professor Nita Miller for her sound advice and friendship; and to Commander John Schmidt for suggesting the thesis and ensuring she stayed on track and finished early.

Thanks also goes to Professor Bob Figlock of the NPS School of Aviation Safety for all of his assistance is gathering the MCAS data and answering numerous questions regarding it.

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DEDICATION

I want to dedicate this to my wonderful husband Ernie. To say it has been a challenging two and a half years with both of us pursuing master's degrees, is a gross understatement. We have succeeded only because we worked together as a team, some days better than others. To our beautiful children, David and Rachel, I love you both so very much. Thank you for understanding why Mommy and Daddy always had so much homework to do and that our "big projects" were important. I look forward to the day when we can relax and just have fun!

To the many friends we have in the Monterey area, especially those at Bethlehem Lutheran Church. They made us feel welcome from the very beginning. Without having any family in the area, we would never have made it without all of our new friends stepping in and filling that void.

To my family in Minnesota, thank you for the support you have given us and the understanding you have shown. I hope that one day we will be able to live in Minnesota so that we can see you more often.

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I. INTRODUCTION

A. BACKGROUND

Naval Aviation is a hazardous endeavor that routinely puts lives and resources at risk, both on the ground and in the air. Naval Aviation's "…goal is to continue to drive mishap rates toward zero while preserving, or even enhancing, our war fighting readiness" (DON, 2000). Much has been done to reduce the number of Class A Flight Mishaps (FMs) since the 1950's, but over the last decade, the FM rate has leveled off (Civarelli, Figlock, & Sengupta, 1997). Human error remains a large contributor to FMs despite efforts to reduce this component. In fact, in order to reach established error reduction goals, attention has now turned to include maintenance and maintainer error (Schmidt, Schmorrow, & Hardee, 1997).

Roberts (1998) studied organizations that successfully manage hazardous operations while experiencing minimal losses, dubbing them High-Reliability Organizations (HROs). Examples of HROs include nuclear submarines and aircraft carriers (Bierly & Spender, 1995; Roberts, 1990). Consequently, Naval Aviation is viewed as a HRO that uses organizational culture to maintain high levels of safety and keep the number of mishaps low. Strong evidence exists that an organization's safety culture impacts maintenance safety (Reason, 1997). That is, the culture has a steady-state effect of being good rather that a short-term effect of getting good.

In 1996, when Naval Aviation first looked at organizational culture for possible causal factors, aircrew error was the primary focus since it had contributed to two-thirds of all Class A FMs since 1990 (Nutwell & Sherman, 1997). The Command Safety Assessment (CSA) was developed to establish a link between safety culture and mishap records. The recent shift to maintenance safety led to the development of the Maintenance Climate Assessment Survey (MCAS) to establish a link between a unit's safety culture and its mishap rate. The MCAS has gone through numerous iterations and was most recently re-validated with the 3rd Marine Air Wing (Harris, 2000; Stanley, 2000). The prototype and modified MCAS was originally administered via paper and pencil and later on Scantron 8200 bubble sheets. Now, the MCAS is available to all Navy and Marine Corps aviation units via the Internet (see Appendix A). As of November 2000, 40 different units had requested to take the on-line version of the MCAS.

B. PURPOSE

The intent of this study is to: 1) determine if administration of the Internet-based MCAS yields results similar to those of the paper-and-pencil version (i.e. its validity and reliability in terms of whether or not any one MOSE area or individual question is determining the outcome of the MCAS); 2) determine whether MCAS results can predict which units are more likely to have MRIs; 3) ascertain whether MCAS results differ between units that experienced recent maintenance incidents and those that did not; and 4) analyze demographic factors to determine if they have an effect on the MCAS responses.

C. PROBLEM STATEMENT

A prototype MCAS was developed to assess maintenance safety climate (Baker, 1998). Oneto (1999) studied the validity and reliability of MCAS by studying various Naval Air Reserve aircraft communities. Goodrum (1999) conducted a similar study by analyzing the 14 squadrons of the Naval Air Reserve Fleet Logistics Wing. Harris (2000) and Stanley (2000) administered the survey to the 3rd Maine Air Wing to examine its U.S. Marine Corps applicability and demographic effects. This study examines the on-line MCAS, its impact on survey results, the relationship with maintenance-related incident (MRI) data and squadron flight hours, and demographic variables. Statistical methods will be used to address the following research questions:

1. Does taking the MCAS on-line yield results similar to when it is administered via paper and pencil?
2. Can the MCAS predict which units are more likely to have MRIs?
3. Can the MCAS distinguish between aviation units that have and do not have MRIs?
4. Do demographics impact survey responses and overall unit results?

D. SCOPE AND LIMITATIONS

For this study, the on-line version of the MCAS is utilized to obtain maintainer perceptions of the command safety climate. MCAS is also being evaluated to assess its effectiveness as a predictor of an aviation unit's safety record. Only Naval Aviation units which supplied a minimum of 20 MCAS respondents are included. In order to protect the units' identities, each unit is referred to by a letter (designation).

The survey is administered where the unit is currently located, with the only requirement being Internet access. Participants include officer and enlisted maintainers. Specifically, only those personnel who are available when the unit chooses to take the survey participate. Different aircraft communities and unit types vary in size; therefore there is variability in the number of participants per unit.

The Naval Aviation Safety Program (OPNAVINST 3750.6Q, 1989) governs the reporting and investigation of all Class A, B, and C incidents. Using MRI reports presents some difficulties since some of the MRI details are lost when the information is entered into the Safety Information Management System (SIMS) database. Also, the governing instruction states that, unlike mishaps, HAZREPs are just recommended, not required, to be reported. Consequently, the number of HAZREPs is underreported in the SIMS database. Lastly, commands have discretion in determining the recorded or reported cost associated with a mishap thereby potentially reducing a Class C MRI, which is required to be reported, to a HAZREP MRI, which may or may not be reported.

Chapter II reviews the literature on organizational culture, climate, high-reliability organizations, the history of MCAS, and the development of HFACS-ME. Chapter III discusses the methodology used in this study. Chapter IV presents the results and Chapter V gives conclusions, findings and recommendations.

II. LITERATURE REVIEW

A. INTRODUCTION

This chapter gives an in-depth literature review to provide an overview of the relationship between organizational climate, maintenance safety and the on-line MCAS. Text books, research papers, theses, and books on the subject are utilized. A discussion of organizational culture is followed by a description of HROs and the history of MCAS. The chapter concludes by summarizing the research and makes recommendations as to how to utilize the relationship between the Human Factors Quality Management Board (HFQMB) and the MCAS and to recommend a plan of action on how to prevent or minimize the number of mishaps in an aviation unit.

B. ORGANIZATIONAL CULTURE

Organizational culture is a field of study that originated in the early 1980's as an offshoot of organizational behavior (Moorhead & Griffin, 1992). Today, numerous books and papers have been written on the topic and researchers now routinely refer to it when tackling more traditional subjects regarding organizations (Moorhead & Griffin, 1992). The culture and climate of an organization affects each of its facets, from retention to safety (Reason, 1997). Fortunately, an organization's culture can be changed, and it is up to the formal and informal leaders to assess the current culture and make changes as necessary.

There is no universally agreed-upon definition of organizational culture, and many prominent authors in the field create their own (Reason, 1997). According to Deal and Kennedy (1982) organizational culture is "the way we do things around here" whereas Peters and Waterman (1982) contend it is "a dominant and coherent set of shared values conveyed by such symbolic means as stories, myths, legends, slogans, anecdotes, and fairy tales." However, there are three common themes found in every definition: 1) all authors agree that individuals in an organization have a set of common values; 2) these values are typically taken for granted by the leadership; and 3) most authors agree there is a symbolic way the values are communicated throughout the organization (Moorhead & Griffin, 1992).

Daft (1998) cites numerous examples of how companies or organizations communicate their values. The most common ways are rites and ceremonies, stories, symbols and language (Daft, 1998). The leaders of an organization must remember that everything they say and do is being closely watched. They are considered visual reminders of the organization's values. If change is necessary, the leader must: 1) create the new vision and effectively communicate it to every member of the organization via speeches, company publications and personal actions; 2) get commitment for the changes from all levels; and finally 3) ensure the changes are made permanent by updating instructions and guidelines and ensuring that all current and new employees receive appropriate training (Daft, 1998).

An organization's culture allows its members to integrate internally and externally. Internal integration is how members learn to work together. External integration is how an organization as a whole successfully meets its mission and interacts with individuals outside of the organization or other institutions (Daft, 1998).

> [An organization's] culture is deep seated and difficult to change, but leaders can influence or manage an organization's culture. It is not easy, and it cannot be done rapidly, but leaders can have an effect on culture (National Defense University, 2001).

Organizational culture has recently been studied in connection with the role maintenance plays in safety in the workplace (Reason, 1997). There is strong evidence that an organization's culture does have an impact on its maintenance safety (Reason, 1997). The reason that maintenance plays a major role in an organization's safety record is rather straightforward. There are three forms of human activity that are occur in hazardous environments: control under normal conditions, control under emergency conditions and maintenance-related activities (Reason, 1997). Per Reason (1997), examples of maintenance-related activities include inspections, planned preventative maintenance, unscheduled work, testing and calibration. Table 1 compares the levels of criticality and frequency of the three forms of activity and the extent to which each can be considered 'hands on.' Maintenance-related activities occur all the time and are typically 'hands on' activities; therefore it is not surprising that maintenance-related activities are the ones that pose the greatest risk of human error.

Activity	**'Hands on'**	**Criticality**	**Frequency**
Normal control	Low	Moderate	High
Emergency control	Moderate	High	Low
Maintenance-related	High	High	High

Table 1. Relative Likelihood of Performance Problems in Universal Human Activities (From Reason, 1997)

Reason (1997) examines where human performance could be "less then adequate," and he claims "that regardless of the domain, all maintenance-related activities require the removal of all fastenings and the disassembly of components, followed by their reassembly and installation." He asserts that most of the problems lie with this latter activity, the reassembly and installation. To illustrate the point, he uses what he calls the "bolt-and-nuts example" (see Figure 1). There is only one way to remove all the bolts, so the chance of error while disassembling is small. However, there are over 40,000 different ways for the nuts to be reinstalled in an incorrect order. Despite the simplicity of the example, it is backed by data from the aircraft manufacturing industry. In two studies of in-flight engine shut downs, approximately 70% of the contributing factors were various forms of installation errors (Reason, 1997).

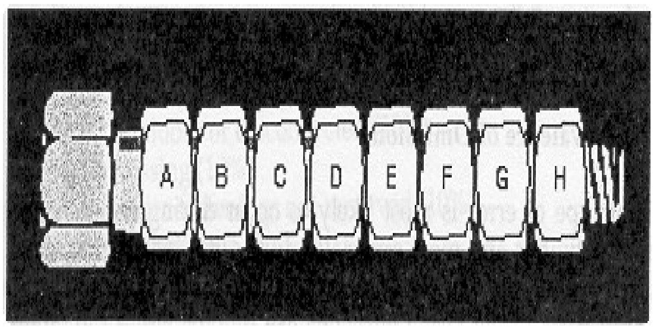

Figure 1. The "Bolt-and-Nuts" Example
(From Reason, 1997)

The errors committed by maintenance personnel generally do not cause a mishap directly. However, the latent conditions initiated by their maintenance-related errors can foster an environment that can ultimately lead to one (Reason, 1997). One explanation for this is Reason's (1997) "Swiss Cheese" Model (See Figure 2), in which he likens an organization to slices of Swiss cheese with each representing a different layer of it. The holes in a slice represent the weaknesses of that layer, which are constantly moving and changing shape. When the slices are lined up, sometimes one layer will block the hole of another layer. This example demonstrates how one layer of an organization can catch a mistake made by another. However, there are times when the holes line up, and a failure is likely to occur. The good news, Reason (1997) contends, is that despite the high frequency of maintenance-related errors, the conditions that cause them are fertile ground for major improvements in the human factors arena.

> [HFAC-ME] facilitates the recognition of absent or defective defenses at four levels, including, Unsafe: *Management Conditions (*Organizational & Supervisory), *Maintainer Conditions*, *Working Conditions*, and *Maintainer Acts* (OPNAVINST 3750.6R Appendix O, 2001).

Figure 3 is a visual depiction of the four levels of absent or defective defenses of the HFAC-ME that are discussed above. Figure 3 illustrates how any one or all could contribute to a FM.

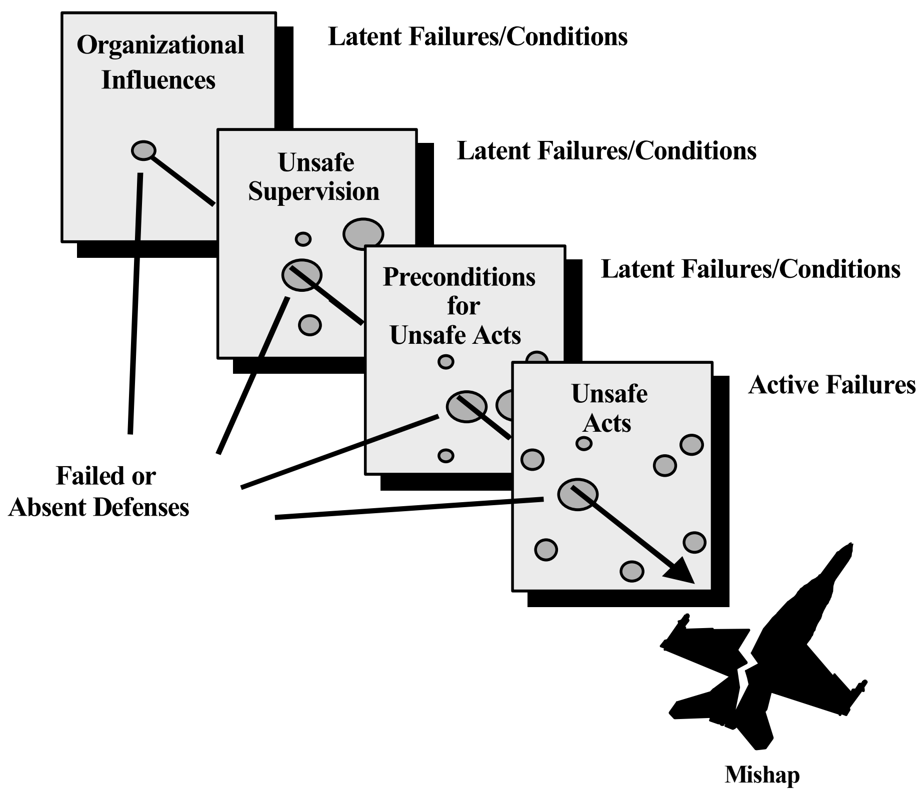

Figure 2. The Reason (1997) "Swiss Cheese" Model

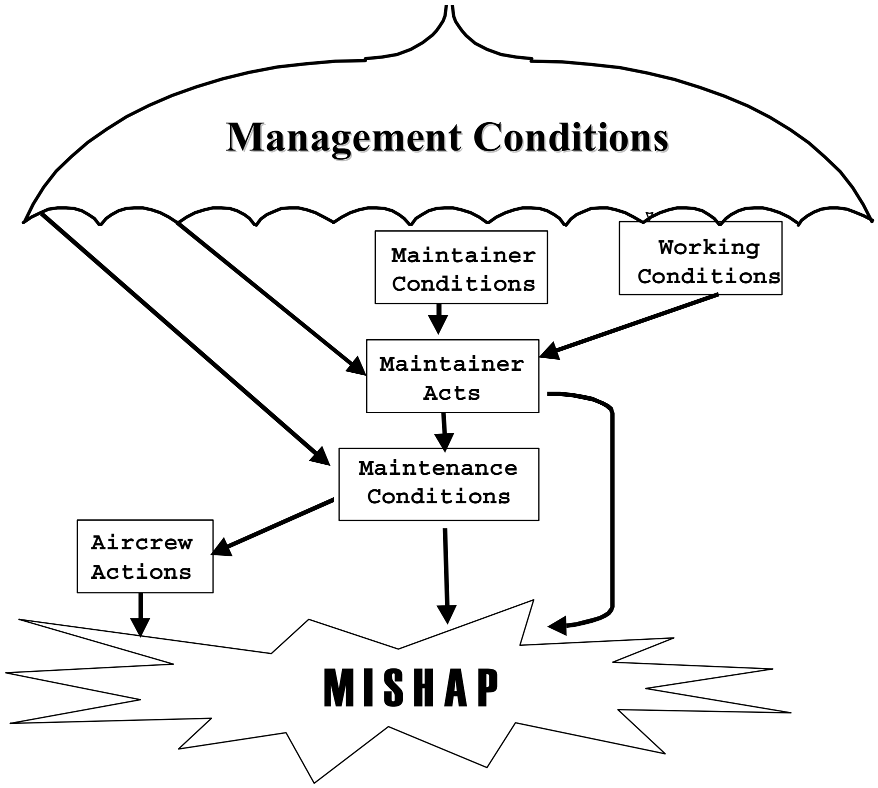

Figure 3. The HFACS - Maintenance Extension (HFACS-ME) (OPNAVINST 3750.6R, Appendix O, 2001)

C. HIGH RELIABILITY ORGANIZATIONS

Engineering a flexible culture is part of the process of instilling a safety culture (Reason, 1997), and organizations with a flexible culture are capable of adapting to changing demands while still being safe. As mentioned earlier, Roberts led the research in this area, calling organizations with this trait HROs (Reason, 1997). They carry out their demanding activities with a very low error rate and an almost complete absence of catastrophic failures and maintain the capacity for meeting periods of very high demand and production. The research done by Roberts and others showed that most of HROs studied were either military organizations or had former military members in key positions. The disciplined work style, a trust in Standard Operating Procedures, and knowledge of how a rank-structure organization works all help to solidify the shared values of an organization and are characteristic of the military and HROs (Reason, 1997).

D. HUMAN FACTORS QUALITY MANAGEMENT BOARD (HFQMB)

After a series of Class A FMs in late 1995 and early 1996, the Naval Postgraduate School's (NPS) School of Aviation Safety became involved in a comprehensive effort to reduce mishaps caused by human factors. The effort produced the HFQMB**,** a panel of experts that contained

> … a broad spectrum of expertise from operational, safety and academic communities. Members include representatives from each [aviation] type commander [Naval Air Forces Atlantic, Pacific, Reserve Force and Aviation Training Command], the Naval Safety Center, senior aviators in operational command and junior aviators from the Navy and Marine Corps, plus aviation safety and human factors professionals (Nutwell & Sherman, 1997).

The HFQMB used a three-part approach: 1) in-depth research into the causes of mishaps and factors affecting human performance; 2) organizational benchmarking to learn from other aviation organizations; and 3) the Command Safety Assessment to identify human error, uncover best practices in the aviation industry and assess the safety climate of Naval Aviation units (Nutwell & Sherman, 1997). The HFQMB concentrated on aircrew error initially since the latter was a contributor in almost 80% of the Class A FMs since 1990 (Schmidt, Schmorrow & Hardee, 1998). During the first 18 months of the HFQMB existence, "the Navy FM rate dropped to its lowest point ever" (Schmidt *et al.* 1998). Energized by these results and recognizing a concern for issues related to aging aircraft, the HFQMB decided to expand its focus to include maintenance operations and adapted a similar three-prong process (Schmidt *et al.* 1998).

Organizational culture and related climate was looked at as a possible causal factor of FMs and HRO research was used to help identify "key organizational issues in order to improve [Naval Aviation's] understanding of the possible influence a Naval command may have" in the event leading up to a FM (Ciaverelli, Figlock, & Sengupta, 1999). The NPS School of Aviation Safety adapted its findings for use in Naval Aviation, calling the resulting framework Model of Organizational Safety Effectiveness (MOSE) (Ciaverelli *et al.* 1999). The five areas of the model are:

- Process Auditing: A system of ongoing checks to identify hazards and correct safety problems.
- Reward System: The expected social rewards and disciplinary action used to reinforce safe behavior, and correct unsafe behavior.
- Quality Control: The policies and procedures for promoting high quality work performance.
- Risk Management: A systematic process used to identify hazards and control operational risk.
- Command and Control: The organization's overall safety climate, leadership effectiveness, and the policies and procedures used in the management of flight operations and safety.

E. MAINTENANCE CLIMATE ASSESSMENT SURVEY (MCAS)

Baker (1998), in his thesis, made adaptations to the MOSE and an aircrew-based survey to develop a prototype MCAS for Naval Aviation maintenance personnel. His survey consisted of 15 demographic and 67 maintenance-related items organized according to the MOSE components. After testing it with 268 participants from three reserve squadrons, he determined that the MOSE can be used to model a unit's maintenance environment. However, a sixth category, Communication/Functional Relationship (CF), was added to accommodate items that did not fit into any of the original five MOSE areas. Through factor analysis, he was then able to pare the survey down to 35 questions.

Goodrum (1999) and Oneto (1999) picked up where Baker's thesis left off. Oneto studied a variety of squadrons in the Naval Air Reserve, surveying 439 maintenance personnel from various aircraft communities: H-60, C-9 and C-130, and P-3. Goodrum studied a Naval Air Reserve Fleet Logistics Support Wing and surveyed nearly 1000 maintainers in three aircraft communities with similar aircraft types: C-9B, C-20, and C-103T. The combined results of the two studies determined that the MCAS is an useful tool for "capturing an aviation maintainer's perceptions of safety in maintenance operations (Harris, 2000)." Goodrum and Oneto proposed nearly identical 40-item surveys, and the current 43-item survey is a direct result of their work.

Harris (2000) and Stanley (2000) took the resulting 43-item survey and assisted in administering it to the 3rd Marine Air Wing. A total of 977 individuals took the survey, and 681 were included in both studies (surveys from underrepresented units and an intermediate maintenance facility were excluded). Harris once again established the validity and reliability of the survey, and extended it to cover USMC units. However, Harris was not able to single out any one of the MOSE components as being a predictor of a squadron's results. Stanley (2000) took the same survey responses and examined the relationship between demographics and MCAS. He found that demographics had little utility in predicting the scores of a given unit.

In early July 2000, the MCAS became available on-line via the NPS School of Aviation Safety website. It is a self-administered survey with nine demographic and 43 maintenance-related items (see Appendix A). Once a squadron has completed the survey, the commanding officer is able to get an instant snapshot of the results. As of 20 November 2000, 40 aviation commands had taken the survey.

Taking the survey on-line presents some slightly different challenges than when taking the paper-and-pencil version. A participant is no longer able to choose to leave an item blank. The on-line MCAS requires a selection of one of the six responses, including "Don't Know" and "Not Applicable", before it will move on to the next question. However, the system does not prevent a participant from selecting the same response for every question. It also requires a basic level of computer knowledge to find the appropriate web site and navigate through it.

F. HUMAN FACTORS ACCIDENT CLASSIFICATION SYSTEM – MAINTENANCE EXTENSION (HFACS-ME)

In an effort to more accurately categorize and analyze human errors that contribute to Naval Aviation mishaps, Naval Aerospace Experimental Psychologists (Wiegman & Shappell, 1997) of the Naval Safety Center created HFACS (Schmidt *et al.* 1998). Features of Bird's Domino Theory, Edward's SHEL Model, and Reason's Swiss Cheese Model are included in HFACS (Schmidt *et al.* 1998).

> Latent conditions and active failures are partitioned into one of three top-level categories. These categories enable an analyst to identify failures a t each of the three levels historically related to accidents: supervisory condition, operator condition, and operator act. These classifications are then used to target appropriate intervention strategies (Schmidt *et al.* 1998).

A maintenance-specific taxonomy, HFACS-ME was developed from HFACS to assist investigations of maintenance-related mishaps. It includes four broad categories of human error (see Figure 3): Management Conditions (a latent condition), Working Conditions (a latent condition), Maintainer Conditions (a latent condition), and

Maintainer Acts (an active condition). The three latent conditions fall under the general area of organizational climate. These are areas that can affect the performance of maintainers, play a role in active failures or unsafe acts by a maintainer and ultimately result in an incident (mishap, hazard, or injury). It is possible for unsafe maintainer acts to turn into a latent maintenance error that aircrew may come across when in the cockpit. Also, latent supervisory errors can result in maintenance-related errors. Table 2, the HFACS-ME Category table, shows how the taxonomy is used. It decomposes the four main first-order categories into second- and third-order subcategories. The second-order categories decompose the first-order categories into two to three smaller areas. The third-order subcategories break down the second-order subcategories further to more specific areas by giving fairly specific examples of what types of errors are considered to be of that particular type (Schmidt *et al*. 1998).

In an effort to assist Naval Aviation to address maintenance-related safety issues, Schmorrow (1998) studied Naval Aviator maintenance mishaps using HFACS-ME. He followed a study done by Schmidt *et al*. (1998), and created a way to conclude quantitatively whether significant patterns of human error in flight mishaps exist. In a related effort, Teeters (1999) used MRMs, HAZREPS and Personal Injury Reports (PIPs). He concluded that the number of incidents with these types of causal factors should decrease if the number of causal factors can be reduced. Fry (2000), in his thesis, concluded that the HFACS-ME taxonomy gives sufficient guidelines for classifying MRM causal factors.

First-order	Second-order	Third-order
Management Conditions	Organizational	Inadequate Processes Inadequate Documentation Inadequate Design Inadequate Resources
	Supervisory	Inadequate Supervision Inappropriate Operations Uncorrected Problem Supervisory Misconduct
Maintainer Conditions	Medical	Adverse Mental State Adverse Physical State Unsafe Limitation
	Crew Coordination	Inadequate Communication Inadequate Assertiveness Inadequate Adaptability/Flexibility
	Readiness	Inadequate Training/Preparation Inadequate Certification/Qualification Personnel Readiness Infringement
Working Conditions	Environment	Inadequate Lighting/Light Unsafe Weather/Exposure Unsafe Environmental Hazards
	Equipment	Damaged/Unserviced Unavailable/Inappropriate Dated/Uncertified
	Workspace	Confining Obstructed Inaccessible
Maintainer Acts	Error	Attention/Memory Knowledge/Rule Skill/Technique Judgment/Decision
	Violation	Routine Infraction Exceptional Flagrant

Table 2. The HFACS – Maintenance Extension Categories (From OPNAVINST 3750.6R, Appendix O, 2001)

G. SUMMARY

HRO research indicates that they are dynamic, complex organizations that are not immune to unsafe trends. Perrow (1984) states that "normal accidents" will happen regardless of an organization's size, structure and nature. With HROs, the accidents tend to happen less often, but tend to be larger when they do. By using reactive measures such as mishap analysis and proactive measures to identify "pathogenic conditions" (Reason, 1997), HROs can work towards eliminating accidents.

Downsizing and budget reductions in recent years have challenged Naval Aviation to find ways to keep operational readiness at an acceptable level (Schmorrow, 1998). Naval Aviation continues to search for ways to reduce the number of accidents and mishaps. This effort will not only save the lives of aircrew and maintainers, but will also keep training, aircraft and maintenance expenses to a minimum. Reducing maintenance-related human error is just one area where safety can be enhanced.

By utilizing HRO research, Naval Aviation takes advantage of the fact that the MOSE parallels Reason's informed culture. Thus, tools such as MCAS and HFACS-ME can be used to reduce maintenance-related human error. Work done by the NPS School of Aviation Safety has shown that when MCAS and HFACS-ME are properly utilized, they are effective in assessing an aviation unit's safety climate and classifying the errors that are present in mishaps, taking the first two steps in risk management: 1) identify the hazard and 2) assess the hazard. These tools may make it easier to aim intervention strategies.

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III. METHODOLOGY

A. RESEARCH APPROACH

This study involves the analysis of data received from the 43-item MCAS, taken by maintenance personnel from 27 Navy and Marine Corps aviation units. The MCAS results are analyzed to make a determination if administration of the Internet-based MCAS yields results similar to those of the paper-and-pencil version and to ascertain if there is a difference between the validity and reliability established for a paper-and-pencil version and for the on-line one. In this case, the validity and reliability refers to whether or not any MOSE area or individual question is dominating the outcome of the survey. Additionally, the results are partitioned by demographics to determine if demographics have an effect on the responses. A comparison of the group mean and an individual unit mean is performed if statistical differences arise. This comparison demonstrates how specific demographic groups differ from the unit as a whole.

B. DATA COLLECTION

1. Subjects

The participants are Navy and Marine Corps officers and enlisted personnel involved in aviation maintenance from 30 units that completed the MCAS on-line. The units comprise active-duty and reserve units from three different communities: Helicopters (Helo), Fixed Wing – Tactical Air (TACAIR), and Fixed Wing – Non-Tactical Air (Non-TACAIR) (see Table 3). Shore maintenance facilities are not included in this study. Since 20 responses was the minimum number MCAS responses identified by the NPS School of Aviation Safety for an adequate unit sample, no unit with fewer than 20 responses was included. This inclusion criterion resulted in 27 of 30 units being included in this study.

	Helo	Fixed Wing-TACAIR	Fixed Wing-Non-TACAIR
USN	5	6	4
USNR	1	1	5
USMC	3	2	0
USMCR	0	0	0

Table 3. Units with at least 20 responses that took the on-line MCAS through 20 November 2000 by service and aircraft type.

Summarized data on mishap and hazard reports for the 27 units included in the sample were obtained from the Navy Safety Center. Only MRIs that occurred between January 1999 and December 2000 were included in this study.

2. Instrument

The MCAS is a self-administered survey consisting of nine demographic and 43 maintenance-related items (see Appendix A). The demographic items are: 1) rank; 2) total years aviation maintenance experience; 3) work center; 4) primary shift; 5) current model aircraft; 6) status (active duty, drilling reservist or active reservist); 7) parent command; and 8) unit's location. The maintenance items are grouped into the six HRO components: process auditing, reward system, quality, risk management, command and control, and communication/functional relationships. The MCAS utilizes a five-point Likert scale to capture participant responses: Strongly Disagree, Disagree, Neutral, Agree, and Strongly Agree (note: options of Not Applicable and Don't Know are also available).

3. Procedure

a. Survey Administration

The MCAS is available to all Navy and Marine Corps aviation units via the Internet. When a unit wants to take the survey, its safety officer contacts the NPS School of Aviation Safety. Each unit is given a set of identification numbers equal in size to the number of personnel expected to take the survey. It is up to the squadron to brief those personnel selected to take the survey on the purpose and importance of the survey. Once at least twenty of the identification numbers actually distributed have been used, a squadron is considered complete and the commanding officer can see the results for his or her squadron.

b. Incident Data Acquisition

The Naval Safety Center database was queried for all squadrons that completed the MCAS for incidents between January 1999 and December 2000. Eleven FMs and 44 HAZREPs were found. Eight of the 27 squadrons had at least one FM during the period of interest. The incident rate for each unit is then calculated. To do this, the number of MRIs and HAZREPS for each unit is totaled and then divided by the total flight hours for the past two years. This number is than standardized to give an incident rate per 100,000 flight hours, which is the standard used within Naval Aviation.

C. DATA ANALYSIS

1. Data Tabulation

Survey responses are available via the website administrator, the NPS School of Aviation Safety. The responses consist of a spreadsheet containing one row per respondent and 57 columns. The first two columns have a running count of the total number of respondents and the date the survey was taken. Columns three through ten represent the seven demographic variables plus two identification codes used by the website administrator. The remaining columns correspond to questions one through 43 of the survey. The 43 items are grouped so as to correspond with the six MOSE components: 1) Process Auditing (questions 1-6), 2) Reward System and Safety Culture (questions 7-14), 3) Quality Assurance (questions 15-20), 4) Risk Management (questions 21-29), 5) Command and Control (questions 30-37) and 6) Communication/Functional Relationships (questions 38-43). The responses are scored as 1, 2, 3, 4, or 5 per the Likert scale corresponding with the following statements: Strongly Disagree, Disagree, Neutral, Agree and Strongly Agree, with additional options of Not Applicable and Don't Know available. The mishap rate for each squadron is computed by dividing the number of mishaps for each squadron that occurred in the January 1999 to December 2000 period by the unit's total number of flight hours for the same period.

2. Statistical Analysis

Summary statistics are computed for each squadron and individual participants. Means are computed for each MOSE area for each squadron and respondent. Principal components analysis is used to determine if any MOSE component or item is dominating the outcome of the survey. ANOVA and MANOVA are conducted to see if the MCAS can detect differences between the MOSE components and the units. Simple linear regression is performed using the units' mean MCAS as the independent variable and their incident rate as the dependent variable to determine if a unit's mean MCAS score can be used to determine a unit is more or less likely to have experienced an incident. Regression is also performed using unit and individual respondent's demographics as the independent variables and the MOSE area means, the overall mean, and incident rate as the dependent variable.

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IV. RESULTS

A. MCAS DESCRIPTIVE STATISTICS

1. Sample

MCAS survey information is collected from the MCAS site-administrator at the NPS School of Aviation. Survey responses from 2,180 individuals were collected. Of these, 365 were from an Aviation Intermediate Maintenance Activity and were not included in this study since that unit provides intermediate maintenance and does not have any aircrew or aircraft assigned. Additionally, 49 surveys are removed because the same response to each item was recorded, 24 surveys from three units are not included because each unit had fewer than the required minimum 20 participants, and nine surveys with “Other” selected as Service were removed because it was found they had undue influence. The remaining 1,731 surveys are addressed in the MCAS Results section. MCAS offers 36 different options for aircraft type. To ease the analysis, the 36 types are divided into three groups: Helo, Fixed Wing-TACAIR, and Fixed Wing-Non-TACAIR. For this study, the following aircraft types are represented: Helo: H-53 and H-60; Fixed Wing-TACAIR: EA-6, F-14, FA-18, and AV-8; Fixed Wing-NON-TACAIR: P-3, E-6, C-130, and C-9.

2. Analysis of Removed Surveys

An effort was made to determine if removing the surveys with the same response biases the Principal Component Analysis. Table 4 lists the frequency and percentages of the surveys removed by ranks. Table 5 shows the response chosen by those who chose the same response for all items. Response four, “Agree,” was selected most often.

Rank	Total # Surveyed	# Removed	% Removed
E1-E3	444	17	3.83%
E4-E5	819	24	2.93%
E6-E9	496	7	1.41%
WO1-O6	56	1	1.79%
Total	1815	49	2.70%

Table 4. Percentage and Count of Removed Surveys by Participant Rank Response

Response	Response #	# of Participants
Not Applicable	0	0
Strongly Disagree	1	2
Disagree	2	0
Neutral	3	12
Agree	4	25
Strongly Agree	5	6
Don't Know	6	4

Table 5. Number of All-Identical Responses by Response Chosen

Figure 4 compares the surveys removed to those retained for this study by respondent rank. It shows that the percent of removed surveys is similar to the percent of retained. Comparing these results to Harris (2000) shows that he removed 61 of 977 original surveys or 6.24%, while for this study 49 of 2,180 original surveys, or just 2.24%, were removed.

Table 6 shows the frequency of surveys removed by unit. The range of removed surveys varies from just over one percent for unit L to over 16 percent for unit M. Investigation of unit M reveals 11 of 66 surveys were removed. It is noted that seven of the 11 removed surveys for unit M were in the E4 – E5 rank group and Power Plants workcenter leading one to hypothesize that those individuals consulted with one another regarding the MCAS prior to taking it. Having the survey available via the Internet eliminates the option of a participant leaving an item unanswered but it is still possible for the same answer to be selected for every item.

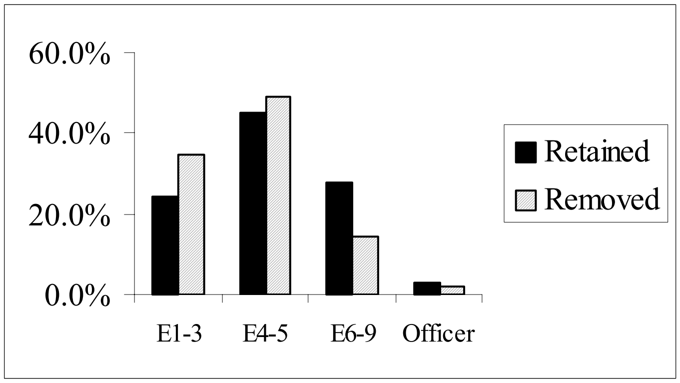

Figure 4. Comparison of Retained and Removed Surveys by Rank

A	B	C	E	F	G	H	J
3.4	3.2	2.1	3.2	6.1	4.2	3.3	4.4

L	M	N	O	P	U	V	Y	Mean
1.1	16.6	3.1	2.1	11.5	7.4	2.7	1.2	4.7

Table 6. Frequency (%) by Unit of Surveys Removed

3. Demographics

The number of survey participants by rank and unit is provided in Table 7. To protect the identity of participating units, letters are used in place of the actual unit name. Approximately 67.3 percent of the respondents are enlisted aviation maintainers in the ranks of E1 – E5. This percentage is lower than the 84.9 percent reported by Harris (2000) in his study of the 3rd Marine Air Wing, the 79.2 percent by Goodrum (1999) in his study of the Fleet Logistics Support Wing and the 81 percent by Oneto (1999) in his study of several aircraft communities within the Naval Air Reserve. However, this study takes in to consideration a much larger number of surveys. All of the units have a similar proportion of E1-E5's, except for those units with a small number of responses (see Figure 5).

4. MCAS MOSE Component Statistics

Table 8 shows the mean response by each of the MOSE categories and unit. The corresponding survey items for each MOSE category are listed in Chapter III, Section C.1 The means for the 43 survey items for each unit can be found in Appendix B.

B. MCAS PRINCIPAL COMPONENT ANALYSIS

To test whether or not the six MOSE components account equally for the majority of the variability in the data, principal component analysis (Hamilton, 1992) is used. A 1761 by 43 matrix of individual survey responses, each row representing one survey response and each column representing one survey item, is used to create a 27 by 43 matrix, with one row for each of the 27 units. Since responses of 0 for "N/A" and 6 for "Don't Know" were not available when Harris (2000) and Stanley (2000) administered the survey and because those responses would artificially lower or raise the menas, they are disregarded in computing the individual item and MOSE category means. Since all items are on the same scale, the covariance matrix is used. A common usage of principal component analysis is determining which survey items are the most important or conversely, which ones can be removed. For this study, it is being used to determine whether each item is contributing approximately equally.

Unit	E1-E3		E4-E5		E6-E9		WO1-O6		TOTAL	
	#	%	#	%	#	%	#	%	#	%
A	16	27.5	25	27.6	10	17.2	5	8.6	58	3.2
B	37	38.9	40	42.1	14	14.7	1	1.1	95	5.3
C	22	4.3	17	36.2	7	14.9	0	0.0	47	2.6
D	0	0.0	19	63.3	11	36.7	0	0.0	30	1.7
E	9	14.5	27	43.5	21	33.8	3	4.8	62	3.4
F	9	18.4	18	36.7	15	30.6	4	8.2	49	2.7
G	16	16.7	33	34.4	41	42.7	2	2.1	96	5.3
H	26	28.3	40	43.5	21	22.8	2	2.2	92	5.1
I	6	20.7	13	44.8	10	34.5	0	0.0	29	1.6
J	15	22.1	31	45.6	16	23.5	3	4.4	68	3.7
K	5	23.8	7	33.3	7	33.3	2	9.5	21	1.2
L	21	23.3	46	51.1	19	21.1	3	3.3	90	5
M	5	7.6	35	53.0	14	21.2	1	1.5	66	3.6
N	30	31.3	42	43.7	15	15.6	6	6.3	96	5.3
O	101	43.2	71	30.3	49	20.9	8	3.4	234	12.9
P	4	15.4	10	38.5	8	30.7	1	3.8	26	1.4
Q	43	40.6	43	40.6	18	16.9	2	1.9	106	5.8
R	19	41.3	17	36.9	10	21.7	0	0.0	46	2.5
S	1	2.4	18	43.9	20	48.8	2	4.9	41	2.2
T	7	11.8	32	54.2	19	32.2	1	1.7	59	3.3
U	0	0.0	13	48.1	11	40.7	1	3.7	27	1.5
V	1	1.4	39	52.7	32	43.2	0	0.0	74	4.1
W	20	18.7	56	52.3	29	27.1	2	1.8	107	5.9
X	0	0.0	1	17.0	5	83.0	0	0.0	6	0.3
Y	8	9.5	41	48.8	32	38.1	2	2.4	84	4.6
Z	0	0.0	16	51.6	14	45.2	1	3.2	31	1.7
AA	2	8.3	12	50.0	10	4.7	0	0.0	24	1.3
BB	4	12.1	19	57.6	8	24.2	2	6.1	33	1.8
CC	0	0.0	14	82.0	3	18.0	0	0.0	17	0.9
DD	0	0.0	0	0.0	0	0.0	1	100.0	1	0.1
Total	427	23.5	795	43.9	489	26.9	55	3.0	1815	100

Table 7. Number and Percentages of Respondents by Rank for each Unit

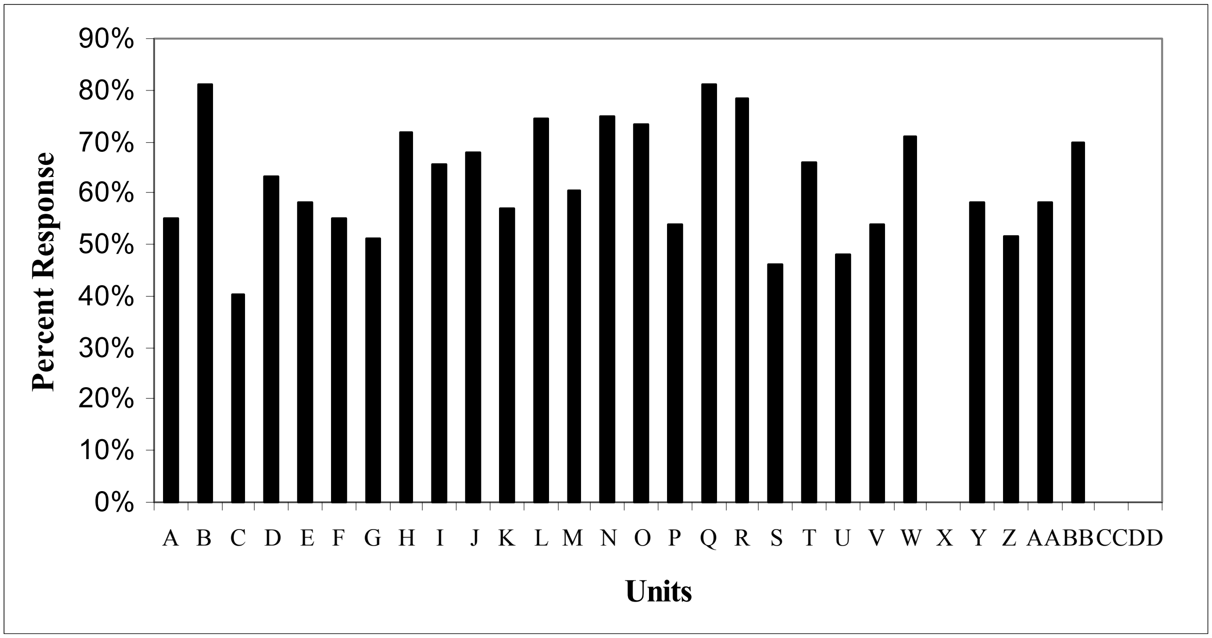

Figure 5. Percentage of MCAS Respondents with Rank E1 – E5 for Each Unit

Figure 6 is a scree-plot that plots the variance contributed by each component for the six MOSE areas. It is apparent by examining figure 6 that the first component accounts for 90.6 percent of the variance of the data. Reviewing the loading plot (see Appendix C) for the loadings of the individual MOSE areas shows that the variance for the first component is shared fairly equally among all six of the MOSE areas. It should be noted that the principal component loadings are the coefficients of the principal components' transformations. Also displayed in Appendix C are the loading plots for each of the 43 survey items grouped into the six individual MOSE areas. These results show that all of the items load approximately equally, from .151 for item 23 to .498 for item 15, across the first component with the exception of item 21 whose loading is -.201 and item 38 whose loading is .702. Item 21 was also noted in Harris' (2000) study as having a negative loading. Examination of item 21 reveals it is the one survey item that is worded negatively. It states: "Multiple job assignments and collateral duties adversely affect maintenance" (see Appendix A). Examination of item 38, which states "Good communication exists up and down the chain of command", reveals it has the most variation of the six questions in the CF MOSE area and had no responses of "Strongly Agree".

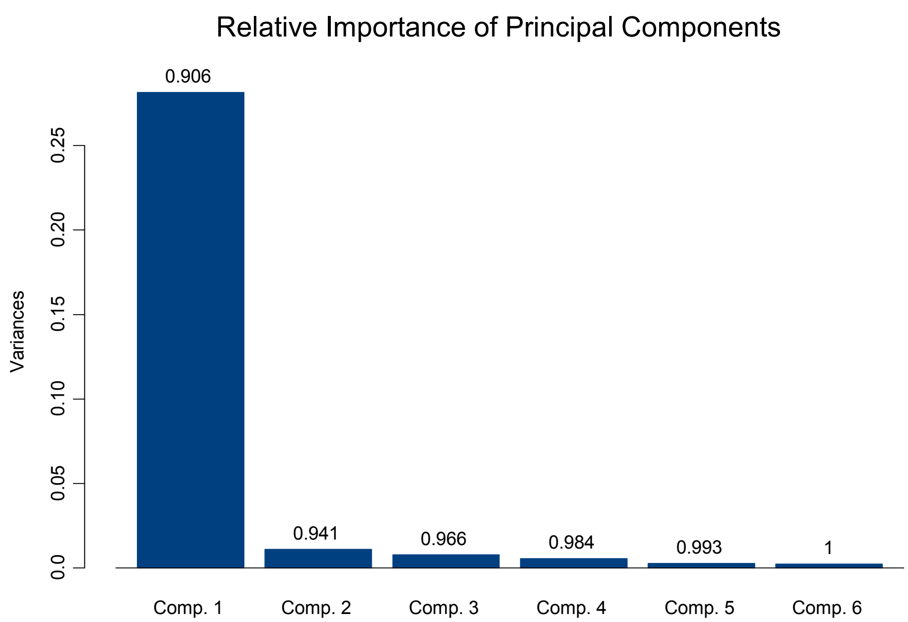

Figure 6. Principal Component Scree-Plot for the MOSE Components

Unit	PA	RS	QA	RM	CC	CF	Mean
A	4.40	4.10	4.40	3.85	4.21	4.15	4.15
B	4.15	3.76	4.08	3.62	3.83	3.79	3.85
C	3.93	3.75	3.83	3.67	3.73	3.73	3.77
D	3.63	3.18	3.45	3.04	3.21	3.17	3.28
E	4.10	3.67	3.91	3.28	3.70	3.67	3.69
F	3.85	3.53	3.55	3.26	3.66	3.66	3.59
G	3.99	3.81	3.85	3.39	3.83	3.76	3.75
H	3.82	3.47	3.64	3.10	3.50	3.37	3.45
I	4.11	3.81	3.97	3.26	3.76	3.79	3.74
J	3.84	3.52	3.84	3.37	3.62	3.46	3.59
K	3.86	3.62	3.89	3.51	3.65	3.53	3.65
L	3.75	3.34	3.54	3.16	3.40	3.39	3.41
M	3.64	3.38	3.69	3.07	3.46	3.45	3.43
N	3.96	3.73	3.91	3.40	3.77	3.66	3.72
O	4.05	3.77	3.85	3.46	3.75	3.64	3.73
P	3.55	3.35	3.51	2.94	3.18	3.17	3.27
Q	3.74	3.21	3.40	3.06	3.31	3.19	3.30
R	4.03	3.70	3.75	3.35	3.71	3.56	3.66
S	3.99	3.92	3.91	3.46	3.93	3.90	3.84
T	3.98	3.52	3.64	3.17	3.54	3.36	3.51
U	3.67	3.37	3.46	2.97	3.19	3.47	3.32
V	3.98	3.71	4.02	3.48	3.79	3.70	3.76
W	3.80	3.58	3.67	3.47	3.74	3.54	3.62
Y	3.94	3.77	3.96	3.43	3.76	3.73	3.74
Z	3.99	3.64	3.98	3.33	3.71	3.63	3.65
AA	4.05	3.80	4.06	3.62	3.79	3.70	3.81
BB	4.11	4.03	4.19	3.77	4.08	3.94	4.01
CC	3.95	3.77	4.07	3.57	3.57	3.53	3.74
DD	3.67	2.63	3.67	2.33	2.88	3.67	3.14
Mean for all Units	**3.92**	**3.63**	**3.81**	**3.35**	**3.66**	**3.60**	**3.64**
Mean for Units w/ >= 20 Participants	**3.91**	**3.60**	**3.82**	**3.32**	**3.63**	**3.60**	**3.63**

Table 8. Mean MCAS Response for all Units and for Units with at least 20 Participants by MOSE Component

C. MCAS MOSE COMPONENT ANALYSIS

Only the 27 units with a minimum of 20 responses are used to conduct additional analysis, ANOVA and MANOVA on the MOSE components. Figures 8 and 9 are box plots displaying the MOSE scores for the six components and the MCAS scores for each of the 27 units, respectively. The mean Likert scale response (1 = "Strongly Disagree", 2 = "Disagree", 3 = "Neutral", 4 = "Agree", 5 = "Strongly Agree") for the MOSE components and the units is 3.64. Responses of 0 = "N/A" and 6 = "Don't Know" were not included. Of note, the mean for Risk Management (RM) is 3.35 with a low of 2.94 for unit P and a high of 3.85 for unit A. The highest-scored component is Process Auditing (PA) with a mean of 3.92, ranging from 3.55 for unit P to 4.40 for unit A. Unit P had the lowest mean score for both RM and PA, while unit A had the highest means for those two components.

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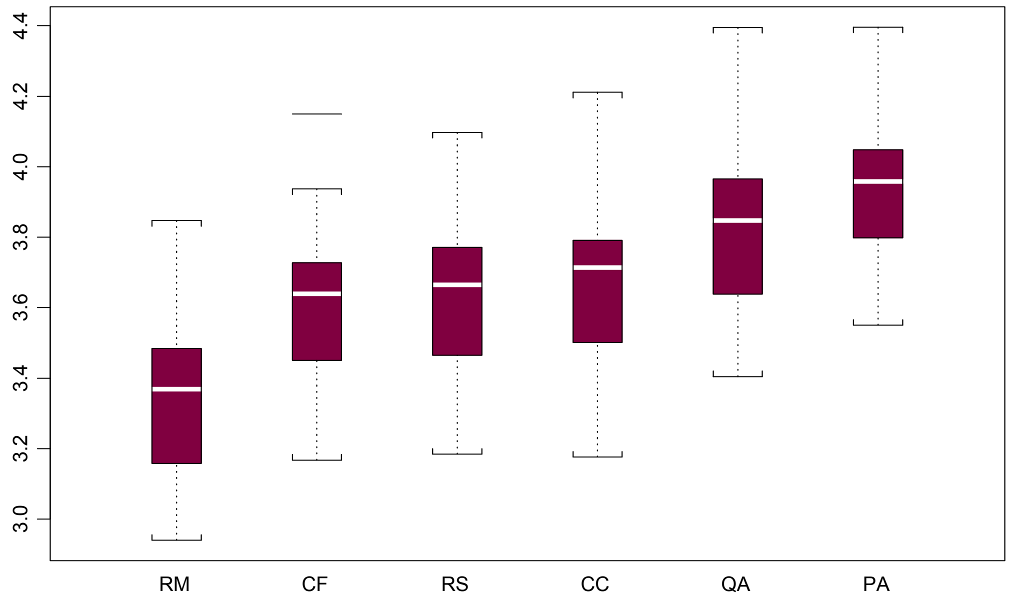

Figure 7. Boxplots of MOSE Component Means

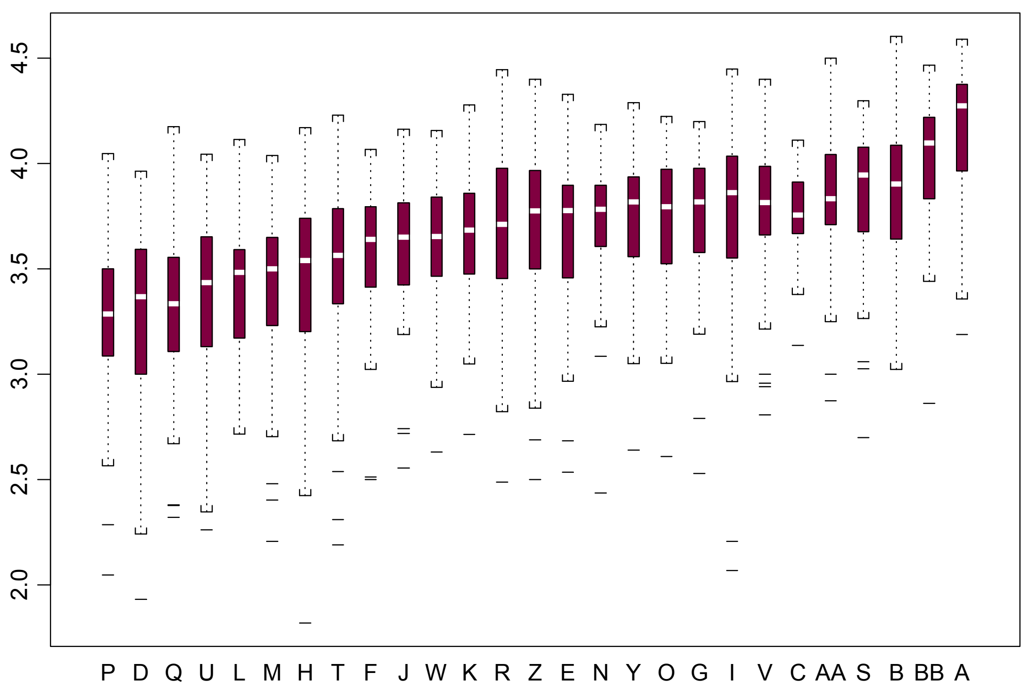

Figure 8. Boxplots of Units' MCAS Means

Table 9 compares Harris' (2000) results with this study. When comparing the current study and Harris', the MOSE mean and range for the MOSE means are similar with the same MOSE components recording the lowest and highest means. For the units, the mean and the range are also comparable, although the highest unit mean for this study with 27 units is more than 0.5 above the overall mean compared to just 0.3 higher in Harris' (2000) study of nine units.

	Harris (2000)	**Hernandez (2001)**
# Units	9	27
MOSE Low Category	RM	RM
MOSE Low Mean	3.24	3.35
MOSE High Category	PA	PA
MOSE High Mean	3.86	3.92
MOSE Mean	3.51	3.64
Unit Low	3.22	3.27
Unit High	3.84	4.15
Unit Mean	3.51	3.64

Table 9. Comparison between Harris' (2000) study and this study

1. Analysis of Variance (ANOVA)

To see if either the squadron or MOSE component displays any effect on the mean survey response, a two-way ANOVA is conducted. A data set of the 27 units (the first factor) and the six MOSE components (the second factor) is used. This means there are 162 possible cross-classifications. The mean item response from Table 8 is the dependent variable. The ANOVA is weighted by the number of participants per unit (see Table 7). The ANOVA model is: MCAS mean is modeled by Unit and the MOSE Components. The mean for each cross-classification consists of a grand mean, a squared effect, a MOSE Component effect, and an error term, where the error terms are independent, and normally distributed with mean zero and constant variance.

Table 10 displays the results of ANOVA analysis. As can be seen, the resulting *p*-values for the null hypotheses that there is no unit effect and no component effect are <.0001. Therefore, there is evidence that at least one unit has a population mean different from the grand mean and that at least one of the MOSE components has a population mean different from the grand mean. These results are also similar to those of Harris (2000).

	df	Sum of Sq	Mean Sq	F	*p*-value
Unit	26	405.37	15.59	42.76	<.0001
Comp	5	343.62	68.72	188.47	<.0001
Residuals	130	47.40	0.36		

Table 10. ANOVA of Unit and MOSE Factors

2. Multiple ANOVA Comparisons

A multiple comparison analysis of the MOSE components factors is conducted using Tukey's procedure. This test determines which MOSE components are significantly different from one another. Using the Studentized Range probability distribution, simultaneous confidence intervals for all pairwise comparisons were computed. Appendix D contains the appropriate S-PLUS code and output for Tukey's procedure for the MOSE components and the individual units. The resulting confidence intervals are the intervals for the differences between true treatment means for each pair. Intervals that do not contain zero mean that the treatment means are statistically different (Devore, 1995). Figure 9 displays the results. The MOSE component means are arranged in increasing order. Underscores show pairs for which the confidence interval contains zero and whose members are therefore not statistically different (distinguishable) from each other. As can be seen, RM, QA, and PA are different from all other components.

RM	**CF**	**RS**	**CC**	**QA**	**PA**
3.35	**3.60**	**3.63**	**3.66**	**3.87**	**3.92**

Figure 9. Identifying Statistically Different MOSE Components

A similar multiple comparison analysis is conducted of the units. See Figure 8. The results of the pairwise comparison are complex since there are numerous comparisons of the 27 units. However, it can be stated that some units have mean scores which differ significantly under the model.

D. INCIDENT DATA ANALYSIS

From January 1999 to December 2000, the 27 units included in this study experienced two class A and eight class C mishaps and 39 HAZREPS. There were no class B mishaps during this timeframe. These MRIs and HAZREPs were attributed to 18 of the 27 units. Table 11 displays the total MRIs with the associated costs. During this timeframe, units B, D, E, I, K, M, O, Q, and S reported no MRIs. Units C and T each had two class C mishaps.

To determine if there is a relationship between a unit's mean MCAS score and their MRIs and HAZREPS, linear regression is performed. First, each unit's incident rate per flight hour is calculated. To do this, the number of MRIs and HAZREPS for the past two years in each unit is computed and then divided by the total flight hours in that period. This number is than standardized to give an incident rate per 100,000 flight hours, which is the standard used within Naval Aviation. Table 12 displays these results along with each unit's mean MCAS.

Unit	Class A ($K)	Class C ($K)	HAZREPs ($K)
A	0	0	1
C	0	224.6 (2)	0
F	17,828.0	0	3
G	17,099.0	0	3
H	0	0	3
J	0	179.4	0
L	0	0	1
N	0	0	4
P	0	31.9	2
R	0	35.1	1
T	0	126.3 (2)	7
U	0	0	3
V	0	0	1
W	0	0	3
Y	0	0	1
Z	0	79.2	1
AA	0	0	1
BB	0	0	4

Table 11. Total MRIs and Associated Costs ($K) between Jan 99 – Dec 00

Simple linear regression is performed with mean MCAS as the independent (or predictor) variable and incident rate as the dependent (or response) variable. Figure 10 show a plot of the resulting linear regression. It is apparent that unit F has high influence, thus affecting the slope coefficient**.** Figure 11 plots the same regression without unit F. Appendix E has the specifics of both regressions. For the model with unit F included, the estimated slope coefficient is –61.37 with an associated t-value of .7203. For the model without F, the estimated slope coefficient is –21.42 and associated t-value of .7378. The relationship between MCAS score and Incident Rate, although slightly negative, is indistinguishable from random variation.

Unit	# Incidents	Flight Hours (FH)	Incident/FH	Mean MCAS
F	4	414	966.28	3.59
T	9	2,986	301.40	3.51
R	2	949	210.70	3.66
U	3	2,982	100.60	3.32
BB	4	4,513	88.63	4.01
W	3	3,443	87.13	3.62
G	4	5,446	73.44	3.75
N	4	6,083	65.75	3.72
P	3	4,871	61.58	3.27
J	1	1,976	50.60	3.59
Z	2	4,183	47.80	3.65
C	2	4,584	43.63	3.77
H	3	7,613	39.31	3.45
A	1	2,615	38.24	4.15
Y	1	3,893	25.68	3.74
V	1	4,601	21.73	3.76
L	1	5,299	18.87	3.41
AA	1	12,542	7.97	3.81
B	0	4,318	0.00	3.85
D	0	1,694	0.00	3.28
E	0	4,413	0.00	3.69
I	0	5,621	0.00	3.74
K	0	2,992	0.00	3.65
M	0	4,889	0.00	3.43
O	0	5,259	0.00	3.73
Q	0	4,905	0.00	3.30
S	0	1,171	0.00	3.84

Table 12. Unit Incidents, Flight Hours, Incident Rate and Mean MCAS Scores for Jan 99 – Dec 00

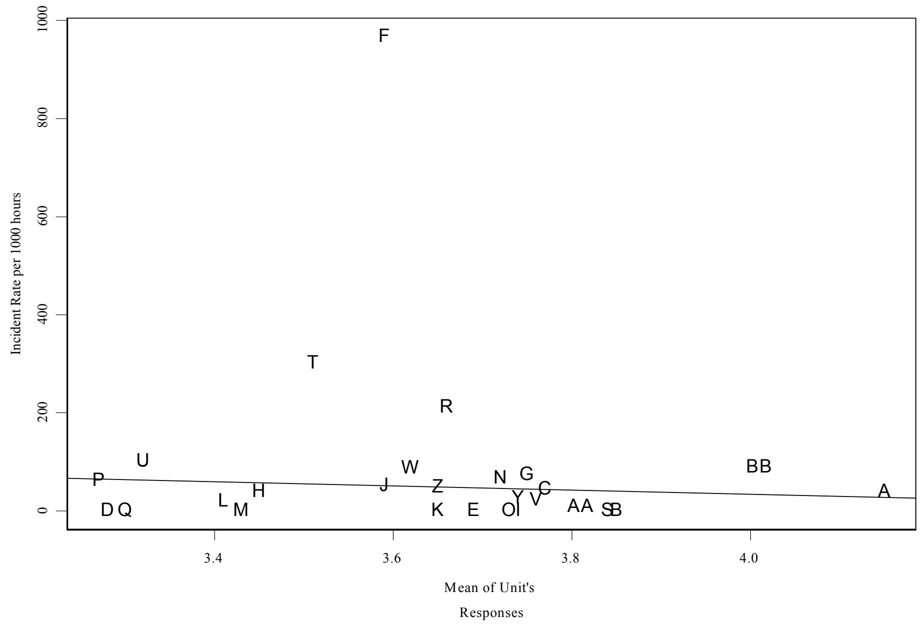

Figure 10. Linear Regression: MCAS Mean vs. Incident Rate, for all 27 Units

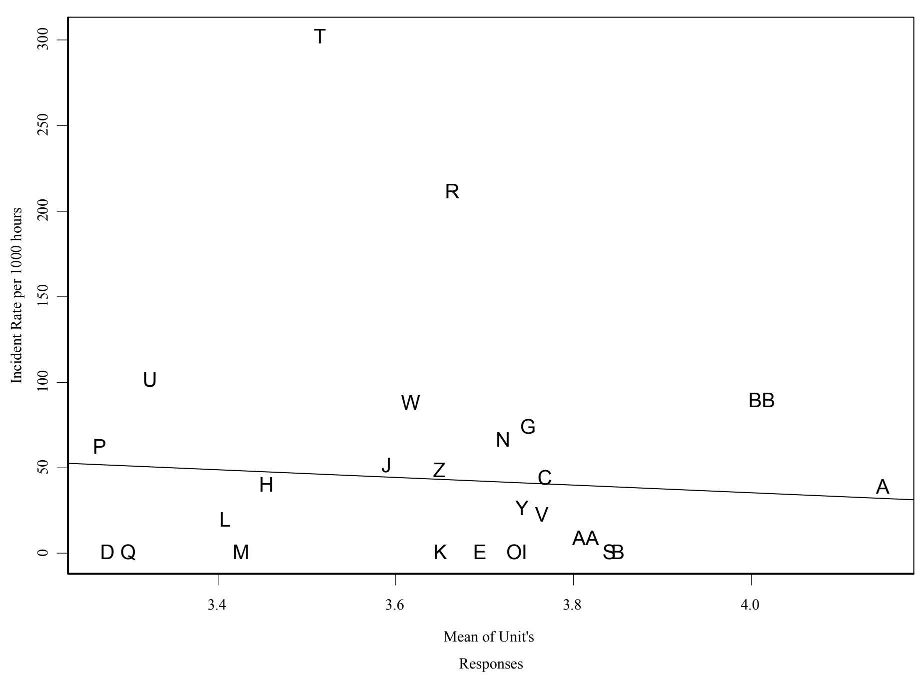

Figure 11. Linear Regression: MCAS Mean vs. Incident Rate, without unit F

E. DEMOGRAPHICS ANALYSIS

Linear models for the six individual MOSE components are fit against the demographic factors of rank, model aircraft, workcenter, status, shift and total years maintenance experience using the linear model function of S-PLUS. The models are then reduced via the `stepAIC` () function, which does stepwise variable selection to minimize the Akaike Information Criterion (Venables & Ripley, 1999). Initial models indicated that some of the categories for rank and workcenter had undue leverage. After conferring with subject matter experts at the Naval Safety Center and NPS School of Aviation Safety, some of the categories for rank and workcenter were combined. The models were than fit again (see Appendix F for details). In all cases, the values of the multiple R-squared, or coefficient of determination, show that the models account for very little of the variance. The best model is the one for RM, accounting for 11.7 percent of the variance. The worst model is that for PA, which explains only 5.1 percent of the variance. In addition, the values for the residual standard error indicate that there is a large spread in the response values, considering that the range of possible responses is only from one to five. When the `stepAIC` () function is applied to the models in an attempt to reduce them, little change occurs (see Table 13). These results are similar to those of Stanley (2000). From the results, the null hypothesis that all of the coefficients are zero is not accepted and there is no evidence that demographics bias the results.

Component	R-Squared (%)	Residual Standard Error
PA	0.049	0.609
RS	0.088	0.649
QA	0.093	0.672
RM	0.117	0.591
CC	0.090	0.631
CF	0.091	0.659

Table 13. R-Squared and Residual Standard Error for Reduced Models

V. SUMMARY, CONCLUSION, AND RECOMMENDATIONS

A. SUMMARY

Organizational leaders, specifically Naval Aviation unit commanders in this case, are ultimately responsible for the safety of their personnel and material resources while simultaneously minimizing risk when accomplishing their given missions. Since 1950, the number of Class A Flight Mishaps (FMs) has decreased, but over the last decade, the FM rate has leveled off (Civarelli, Figlock, & Sengupta, 1997). Human error remains a large contributor to FMs despite efforts to reduce this component. In fact, in order to reach established error reduction goals, attention has now turned to include maintenance and maintainer error (Schmidt, Schmorrow, & Hardee, 1997).

The main objective of this study was to determine if administration of the Internet-based MCAS yields results similar to the paper-and-pencil version (i.e. its validity and reliability in terms of whether or not any MOSE area or individual question is determining the outcome of the MCAS). Of secondary interest was whether MCAS results differ between units that had experienced recent maintenance-related incidents and those that had not. The final item of interest was whether demographic factors have an effect on MCAS responses. This research involved 2,180 survey responses from the first four months of the MCAS being available via the Internet and the analysis of 49 MRIs from between January 1999 and December 2000.

B. CONCLUSIONS

This study shows that the MCAS administered via the Internet is just as effective as the paper-and-pencil version at capturing a maintainer's perception of maintenance safety. Principal component analysis did not identify any one MOSE component or question that was responsible for controlling the outcome of the survey. Some surveys were removed because the same response was selected for each of the 43 survey items. However, since the overall percentage of removed surveys was small, just 2.24%, and the distribution of ranks associated with those surveys was similar to the overall distribution of ranks, it is determined they do not effect the outcome. The Internet-based MCAS does not allow an individual to skip a survey item. A response has to be selected before the program will go to the next item. However, the program does not prevent the same response being selected for every item. One minor finding was with regard to item 21. It was found to load negatively in the first principal component due to the negative wording of the question.

ANOVA and multiple comparison testing determined that the MCAS is able to detect differences between the MOSE components and the unit's MCAS response. The analysis showed RM has the lowest mean among the six MOSE components and PA the highest. This is consistent with the study done by Harris (2000).

Analysis of the MRIs of the 27 units detected a slight negative relationship between a unit's mean MCAS and its incident rate. However, with just 27 units and nine of them having zero MRIs, the relationship is indistinguishable from random variation. It may be that a unit's safety awareness typically increases immediately following any mishap it experiences. It is also important to remember that the safety climate of a unit with regard to its commander lasts at most two years and changes even more frequently at lower levels of the unit. Each of these changes will affect how at least a portion of the unit perceives the safety climate of the unit. Because the range of mean MCAS score for units with no MRIs and those with at least one overlap, it is not possible to provide a profile of a unit more likely to have a MRI from this data.

Linear models are fit using the six MOSE areas as the dependent variable and the individual demographic factors as the independent variables. In every case, the resulting model show the demographic factors account for very little of the variance. Since there is no right answer for any of the survey items and they are all subjective perceptions, the human element accounts for a majority of the variance. However, since the variance cannot be adequately explained by the demographic factors, there is no evidence of a demographic effect when the MCAS is administered via the Internet.

All of the above findings suggest that the on-line MCAS yields results similar to those of the paper-and-pencil version. The biggest difference was that fewer surveys are removed since it is not possible to leave an item blank. To further reduce the number of surveys that have to be removed, a modification to the software could be made to disallow the same response to all items.

C. RECOMMENDATIONS

Based on the conclusions from this study, a number of recommendations are listed below:

1. Risk Management maintenance processes should be reviewed by all Naval Aviation units since this area consistently is ranked the lowest of the six MOSE areas.

2. Minor modifications of the MCAS should be considered, including, positively wording item 21 so that it is in line with the other 42 items, randomizing the survey items with respect to the MOSE components to eliminate the possibility of response order effects, and modifying the software so that a participant cannot choose the same response for every survey item.

3. In order to accurately determine if a relationship between perceptions of maintenance safety and actual safety records exist, require, that at a minimum, all Naval Aviation units take the MCAS during the same 30-day period and repeat this for three to four years. This would give a starting point or base line for each unit for year-to-year comparisons of their mean MCAS scores and incident rates.

Implementation of these recommendations will yield a more useful and effective MCAS for use by all Naval Aviation units.

One area for further research regarding the MCAS and maintenance safety throughout the Navy as a whole is investigating the feasibility of adapting the MCAS to afloat and ashore units. As recent current events have shown, on the USS COLE and USS GREENVILLE, for example, organizational mishaps/accidents in the Navy happen to all types of units, not just aviation units. Application of organizational climate research and maintenance safety could ultimately make all Navy and Marine Corps units more aware of how organizational climate effects safety and reduce future incidents and accidents.

APPENDIX A. MCAS ITEMS

As of the date of this thesis, the website for the MCAS is:
http://web.nps.navy.mil/~avsafety/safesurv.htm**.**

PART 1. DEMOGRAPHICS

1. Rank: E1 - E3, E4 - E5, E6 - E7, E8 - E9, WO 1 - 4, O1 - O3, O4 – O6
2. Total Years Aviation Experience: <1, 1 - 2, 3 – 5, 6 – 10, 11 – 15, 16 – 20, 20+
3. Work Center: Airframes, Avionics, Flight Line, Maintenance Control, Ordnance, Power Plants, QA, Survival, Other
4. Primary Shift: Day, Night
5. Current Model Aircraft: AH–1, AV-8, C-2, C-9, C-12, C-20, C-26, C-35, C-37, C-40, C-130, E-2. E-6, EA-6, F-5, F-14, FA-18, H-1, H-2, H-3, H-46, H-53, H-60, P-3, PIONEER, S-3, T-1, T-2, T-6, T-34, T-37, T-44, T-45, TA-4, TH-57, V-22
6. Status: Regular, Active Reserve, Drilling Reserve
7. Service: USN, USMC, Other
8. Parent Command: CNAL, CNAP, CNARF, CNATRA, NAVAIR, CNO, 1 MAW, 2 MAW, 3 MAW, 4 MAW, CMC, COMCAB EAST, COMCAB WEST, Other
9. Unit's Location: Ashore, Afloat, Overseas, FRS

PART 2. SURVEY ITEMS

A. PROCESS AUDITING

1. The command adequately reviews and updates safety procedures.
2. The command monitors maintainer qualifications and has a program that targets training deficiencies.
3. The command uses safety and medical staff to identify/manage personnel at risk.
4. CDIs/QARs routinely monitor maintenance evolutions.
5. Tool Control and support equipment licensing are closely monitored.
6. Signing off personnel qualifications are taken seriously.

B. REWARD SYSTEM AND SAFETY CULTURE

7. Our command climate promotes safe maintenance.
8. Supervisors discourage SOP, NAMP or other procedure violations and encourage reporting safety concerns.
9. Peer influence discourages SOP, NAMP or other violations and individuals feel free to report them.
10. Violations of SOP, NAMP or other procedures are not common in this command.
11. The command recognizes individual safety achievement through rewards and incentives.

12. Personnel are comfortable approaching supervisors about personal problems/illness.
13. Safety NCO, QAR and CDI are sought after billets.
14. Unprofessional behavior is not tolerated in the command.

C. QUALITY ASSURANCE

15. The command has a reputation for quality maintenance and set standards to maintain quality control.
16. QA and Safety are well respected and are seen as essential to mission accomplishment.
17. QARs/CDIs sign-off after required actions are complete and are not pressured by supervisors to sign-off.
18. Maintenance on detachments is of the same quality as that at home station.
19. Required publications/tools/equipment are available, current/serviceable and used.
20. QARs are helpful, and QA is not "feared" in my unit.

D. RISK MANAGEMENT

21. Multiple job assignments and collateral duties adversely affect maintenance.
22. Safety is part of maintenance planning, and additional training/support is provided as needed.
23. Supervisors recognize unsafe conditions and manage hazards associated with maintenance and the flight-line.
24. I am provided adequate resources, time, personnel to accomplish my job.
25. Personnel turnover does not negatively impact the command's ability to operate safely.
26. Supervisors are more concerned with safe maintenance than the flight schedule, and do not permit cutting corners.
27. Day/Night Check have equal workloads and staffing is sufficient on each shift.
28. Supervisors shield personnel from outside pressures and are aware of individual workload.
29. Based upon my command's current assets/manning it is not over-committed.

E. COMMAND AND CONTROL

30. My command temporarily restricts maintainers who are having problems.
31. Safety decisions are made at the proper levels and work center supervisor decisions are respected.
32. Supervisors communicate command safety goals and are actively engaged in the safety program.
33. Supervisors set the example for following maintenance standards and ensure compliance.

34. In my command safety is a key part of all maintenance operations and all are responsible/accountable for safety.
35. Safety education and training are comprehensive and effective.
36. All maintenance evolutions are properly briefed, supervised and staffed by qualified personnel.
37. Maintenance Control is effective in managing all maintenance activities.

F. COMMUNICATION / FUNCTIONAL RELATIONSHIPS

38. Good communication exists up/down the chain of command.
39. I get all the information I need to do my job safely.
40. Work center supervisors coordinate their actions.
41. My command has effective pass-down between shifts.
42. Maintenance Control troubleshoots/resolves gripes before flight.
43. Maintainers are briefed on potential hazards associated with maintenance activities.

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APPENDIX B. ITEM MEANS BY UNIT

Unit	q1	q2	q3	q4	q5	q6	q7	q8	q9	q10	q11	q12	q13	q14	q15	q16	q17	q18
A	4.50	4.34	4.21	4.50	4.43	4.39	4.59	4.33	3.94	4.33	3.51	4.11	3.87	4.09	4.57	4.52	4.39	4.31
B	4.24	4.07	3.99	4.35	4.17	4.16	4.26	4.01	3.57	3.76	3.02	3.90	3.77	3.88	4.60	4.17	3.87	4.01
C	4.00	3.91	3.74	4.00	4.11	3.82	4.07	3.93	3.68	3.63	3.14	3.98	3.82	3.76	3.93	3.96	3.88	3.79
D	3.70	3.67	3.14	3.93	3.60	3.70	3.50	3.28	3.21	3.10	2.59	3.66	3.28	2.87	3.40	3.87	3.54	3.37
E	4.14	4.13	3.98	4.30	4.33	3.72	3.86	3.90	3.54	3.59	3.46	3.75	3.68	3.54	4.25	3.85	3.75	3.98
F	3.93	3.81	3.60	4.07	4.02	3.67	3.98	3.60	3.24	3.45	3.15	3.89	3.08	3.79	3.67	3.48	3.57	3.23
G	4.07	4.00	3.81	4.15	4.14	3.77	4.08	3.92	3.71	3.75	3.57	3.87	3.54	4.00	4.20	3.94	3.74	3.72
H	3.78	3.84	3.66	4.17	3.80	3.67	3.67	3.72	3.52	3.38	2.99	3.71	3.19	3.52	3.70	3.78	3.37	3.25
I	4.17	4.07	3.97	4.45	4.14	3.90	4.17	3.55	3.54	3.97	4.00	3.90	3.55	3.83	4.34	4.03	3.86	3.93
J	3.88	3.81	3.54	4.16	3.91	3.76	3.86	3.73	3.53	3.61	2.74	3.63	3.38	3.69	4.15	3.82	3.81	3.95
K	3.71	4.05	3.65	4.10	3.95	3.67	4.10	3.55	3.45	3.61	3.38	3.95	3.10	3.81	4.19	3.62	3.86	4.28
L	3.90	3.73	3.52	4.11	3.61	3.62	3.53	3.61	3.44	3.26	3.06	3.53	3.17	3.14	3.85	3.30	3.44	3.35
M	3.78	3.66	3.38	3.93	3.57	3.49	3.50	3.48	3.40	3.22	2.77	3.73	3.25	3.56	4.00	3.79	3.60	3.12
N	4.06	4.01	3.82	4.16	3.92	3.79	4.04	3.86	3.55	3.61	3.30	3.78	3.70	3.94	4.18	3.96	3.86	3.85
O	4.12	4.02	3.79	4.22	4.18	3.98	3.99	4.02	3.72	3.64	3.37	3.91	3.57	3.87	3.94	3.97	3.90	3.79
P	3.83	3.23	3.17	4.05	3.68	3.39	3.13	3.48	3.29	3.45	3.10	3.52	3.62	3.26	3.70	3.57	3.50	3.05
Q	3.80	3.46	3.29	4.17	3.83	3.85	3.22	3.55	3.29	3.15	2.38	3.40	3.22	3.47	3.99	3.60	3.11	3.48
R	4.05	3.86	3.64	4.36	4.11	4.11	4.18	3.95	3.62	3.61	3.02	3.73	3.69	3.71	4.44	4.00	3.57	3.71
S	4.03	4.05	3.94	4.16	4.11	3.63	4.26	4.10	3.77	3.69	3.68	4.00	4.00	3.85	4.13	4.08	4.00	3.52
T	4.23	4.03	3.88	4.07	4.05	3.61	3.66	3.68	3.55	3.38	3.46	3.60	3.25	3.59	4.05	3.78	3.53	3.51
U	3.80	3.13	3.62	4.04	3.74	3.68	3.57	3.70	3.41	3.26	2.52	3.70	3.38	3.43	3.04	3.65	3.52	3.48
V	4.09	3.93	3.52	4.24	4.10	3.97	4.04	3.81	3.70	3.86	3.00	3.89	3.67	3.71	4.40	4.00	4.01	3.97
W	4.08	3.72	3.55	4.16	3.83	3.47	4.02	3.89	3.53	3.44	3.58	3.59	3.15	3.43	3.95	3.82	3.73	3.49
Y	4.05	3.82	3.71	4.29	3.94	3.76	4.06	3.96	3.51	3.79	3.56	3.98	3.63	3.59	4.26	3.91	3.87	3.78
Z	4.18	3.90	3.54	4.37	4.13	3.80	3.97	3.62	3.50	3.68	3.47	3.87	3.34	3.68	4.40	4.03	3.96	3.83
AA	4.04	3.92	3.88	4.50	4.13	3.83	4.29	4.05	3.48	3.83	3.54	3.79	3.52	3.92	4.38	4.00	3.96	3.85
BB	4.30	3.86	3.63	4.32	4.29	4.16	4.22	4.13	3.59	3.87	3.90	4.31	4.00	4.23	4.47	4.10	4.13	4.21

Unit	q19	q20	q21	q22	q23	q24	q25	q26	q27	q28	q29	q30	q31	q32	q33	q34	q35	q36
A	4.04	4.54	3.19	4.30	4.38	3.80	3.70	4.34	3.36	3.96	3.58	4.02	4.29	4.35	4.36	4.42	4.16	4.11
B	3.77	4.10	3.21	4.09	4.23	3.51	3.64	3.64	3.09	3.66	3.52	3.55	3.88	4.09	3.98	4.15	4.04	3.82
C	3.64	3.76	3.56	3.91	3.98	3.73	3.68	3.49	3.51	3.67	3.55	3.71	3.78	3.71	3.76	3.96	3.84	3.73
D	2.63	3.90	3.96	3.50	3.80	2.61	2.50	3.18	1.93	3.37	2.54	3.00	2.82	3.53	3.52	3.55	3.30	3.10
E	3.86	3.78	3.30	3.88	4.03	2.97	3.24	3.43	2.53	3.40	2.68	3.12	3.63	3.90	4.00	3.83	3.88	3.78
F	3.59	3.76	3.33	3.80	3.77	3.28	3.02	3.58	2.50	3.56	2.51	3.28	3.80	3.73	3.81	3.83	3.64	3.49
G	3.58	3.87	3.47	3.99	3.97	3.19	3.28	3.84	2.53	3.42	2.79	3.35	3.82	3.93	3.89	4.12	3.84	3.67
H	3.54	3.89	3.78	3.75	4.06	2.88	2.81	3.18	1.82	3.22	2.42	3.20	3.20	3.73	3.74	3.87	3.55	3.43
I	3.48	4.14	3.52	4.07	4.17	2.97	3.28	3.55	2.21	3.48	2.07	3.29	3.86	3.86	3.72	4.03	3.72	3.69
J	3.42	3.91	3.40	3.69	3.88	3.37	3.31	3.45	2.72	3.36	3.21	3.19	3.45	3.63	3.85	3.75	3.76	3.72
K	3.86	3.55	3.15	3.71	4.10	3.71	3.48	3.71	2.71	3.62	3.35	3.07	3.95	3.80	3.86	3.76	3.67	3.48
L	3.67	3.62	3.35	3.56	3.78	2.93	3.04	2.83	2.72	3.25	2.94	3.08	3.40	3.53	3.56	3.57	3.59	3.32
M	3.56	4.04	3.41	3.59	3.81	2.48	3.04	3.21	2.21	3.32	2.40	2.98	3.65	3.63	3.70	3.50	3.48	3.23
N	3.83	3.76	3.48	3.95	3.89	3.24	3.62	3.60	2.44	3.22	3.08	3.40	3.70	3.87	3.87	4.08	3.87	3.62
O	3.52	3.99	3.29	3.95	4.12	3.35	3.50	3.71	2.61	3.47	3.05	3.39	3.62	3.86	3.96	4.00	3.90	3.70
P	3.43	3.78	3.61	3.22	3.70	2.57	2.74	3.09	2.05	3.10	2.29	2.88	3.00	3.48	3.22	3.43	3.48	2.77
Q	2.70	3.54	3.57	3.50	3.71	2.67	3.03	2.82	2.32	3.14	2.74	3.02	3.24	3.47	3.56	3.60	3.33	3.25
R	2.82	3.96	3.16	4.00	4.09	2.93	3.24	3.61	2.49	3.56	3.05	3.56	3.84	3.82	3.89	4.00	3.76	3.47
S	3.79	3.92	3.03	4.03	3.97	3.31	3.26	4.08	2.70	3.47	3.06	3.43	4.05	3.81	3.71	4.18	3.71	4.30
T	3.33	3.61	3.47	3.84	4.02	2.68	2.98	3.43	2.19	3.27	2.54	3.17	3.10	3.79	3.75	4.02	3.77	3.56
U	3.26	3.78	3.52	3.30	3.65	2.35	2.26	3.32	2.53	3.30	2.35	3.29	3.09	3.43	3.57	3.57	3.26	2.83
V	3.87	3.88	2.96	3.97	4.14	3.41	3.52	3.74	2.94	3.66	2.81	3.48	3.68	4.00	3.93	4.07	3.90	3.71
W	3.30	3.73	3.65	4.02	3.90	3.14	3.35	3.56	2.94	3.50	3.14	3.22	3.57	3.92	3.82	4.09	3.84	3.81
Y	3.94	3.89	3.05	3.89	4.09	3.49	3.15	3.76	2.64	3.56	3.08	3.22	3.65	3.90	3.93	4.06	3.85	3.81
Z	3.62	4.03	3.60	3.93	4.17	3.00	3.13	3.57	2.50	3.37	2.69	3.48	3.53	4.00	3.97	4.00	3.80	3.70
AA	4.17	3.96	3.25	4.13	4.04	3.75	3.79	3.83	2.88	3.88	3.00	3.30	3.79	3.83	4.04	4.13	3.88	3.63
BB	4.06	4.16	2.86	4.16	4.28	3.74	3.77	3.94	3.80	3.83	3.44	3.74	4.10	4.24	4.23	4.23	4.13	4.00

Unit	q37	q38	q39	q40	q41	q42	q43
A	3.96	3.89	4.16	4.13	4.35	4.11	4.27
B	3.24	3.41	4.05	3.72	4.05	3.55	4.07
C	3.38	3.56	3.91	3.69	3.67	3.84	3.69
D	2.83	2.24	3.52	3.00	3.14	3.59	3.55
E	3.42	3.24	3.72	3.69	3.80	3.78	3.83
F	3.66	3.41	3.65	3.80	3.89	3.62	3.67
G	3.93	3.45	3.73	3.71	3.70	4.00	3.98
H	3.25	2.78	3.51	3.54	3.16	3.61	3.62
I	3.86	3.66	3.86	3.79	3.79	3.79	3.86
J	3.56	2.56	3.57	3.70	3.55	3.65	3.80
K	3.43	3.05	3.62	3.80	3.19	3.68	3.90
L	3.11	2.79	3.53	3.56	3.42	3.55	3.63
M	3.36	2.70	3.45	3.60	3.59	3.64	3.66
N	3.64	3.36	3.74	3.66	3.61	3.90	3.72
O	3.46	3.15	3.68	3.79	3.68	3.72	3.84
P	3.04	2.64	3.13	3.30	3.35	3.33	3.27
Q	2.93	2.38	3.35	3.38	3.33	3.31	3.39
R	3.33	3.13	3.75	3.98	3.24	3.45	3.82
S	4.16	3.46	3.95	3.79	3.91	4.05	4.27
T	3.14	2.31	3.46	3.38	3.43	3.76	3.91
U	2.52	2.57	3.61	3.48	3.80	3.55	3.96
V	3.51	3.21	3.81	3.69	3.81	3.71	3.99
W	3.66	2.63	3.73	3.72	3.60	3.60	4.02
Y	3.48	3.25	3.82	3.56	3.83	3.86	4.00
Z	3.21	2.84	3.67	3.90	3.77	3.79	3.83
AA	3.71	3.29	3.83	3.75	3.54	3.77	4.00
BB	3.94	3.60	4.07	3.90	4.12	3.83	4.13

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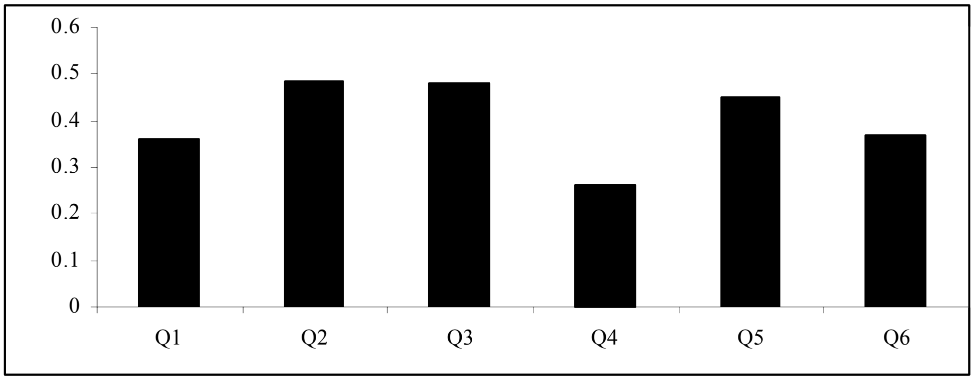
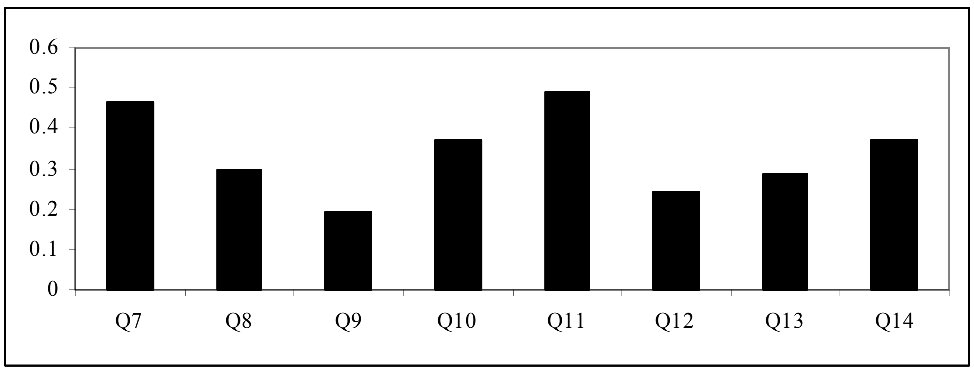
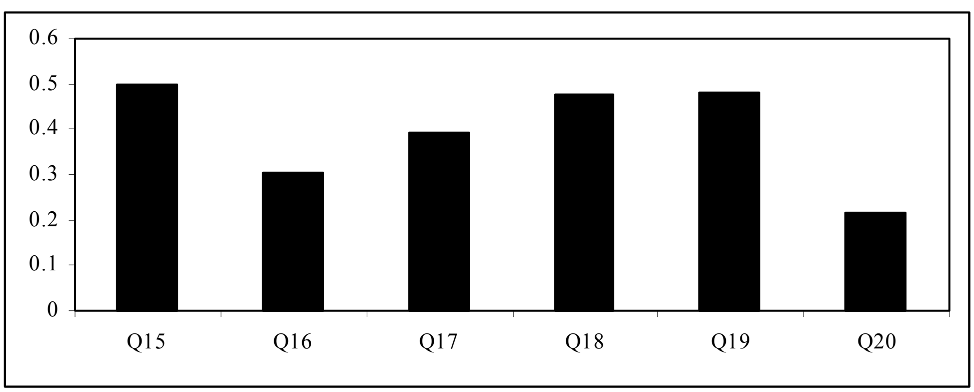
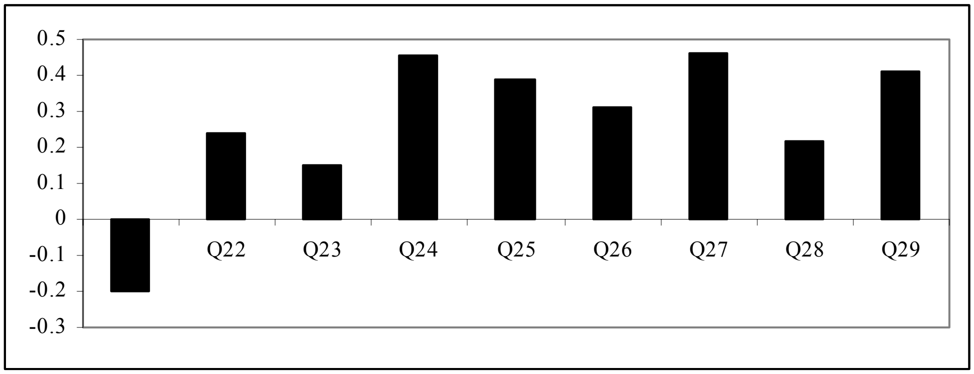
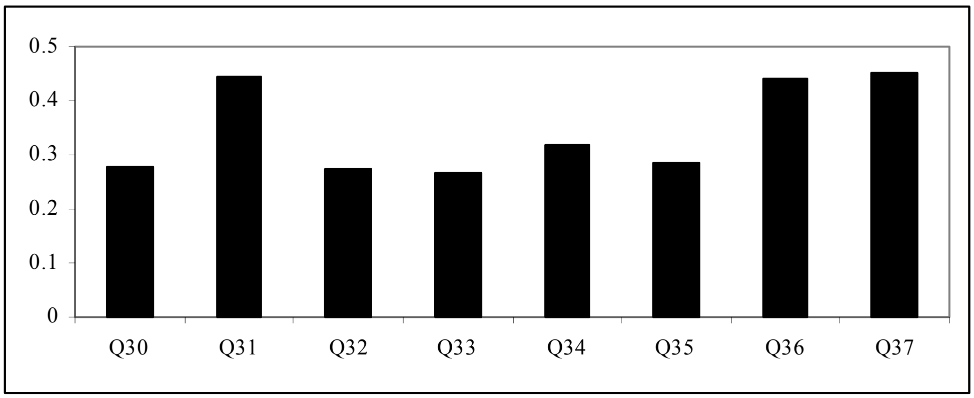
APPENDIX C. UNIT COMPONENT ONE LOADINGS

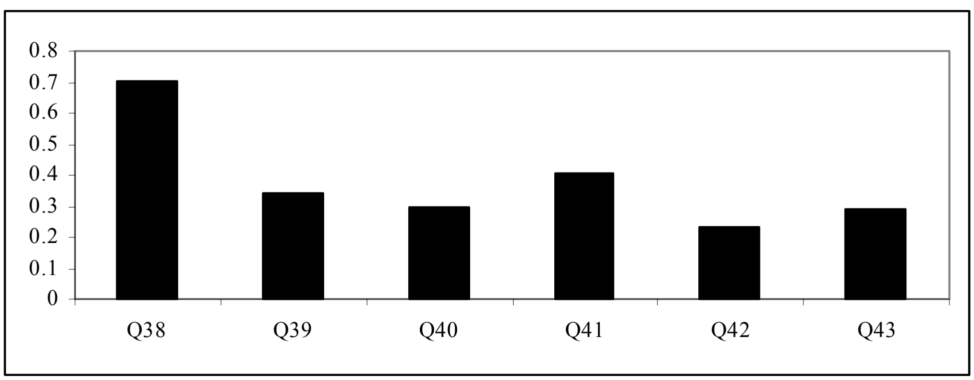







0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
Q22
Q23
Q24
Q25
Q26
Q27
Q28
Q29


0.5
0.4
0.3
0.2
0.1
0
Q30
Q31
Q32
Q33
Q34
Q35
Q36
Q37


0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Q38
Q39
Q40
Q41
Q42
Q43

APPENDIX D. S-PLUS CODE FOR TUKEY'S PROCEDURE

```
attach(squadMOSE)
> tmn_squadMOSE
> tmn1_data.frame(Avg=unlist(c(tmn[,-1])), Squad=dimnames(tmn[,-
+ 1])[[1]][row(tmn[,-1])], Comp=dimnames(tmn[,-1])[[2]][col(tmn[,-1])],
+ weights = SquadDem2$N)

> tmnaov_anova(aov(Avg~Squad+Comp, data = tmn1, weights = tmn1$weights))
> tmnaov
Analysis of Variance Table

Response: Avg

Terms added sequentially (first to last)
          Df Sum of Sq  Mean Sq  F Value Pr(F)
    Squad  26  405.3787 15.59149  42.7584     0
     Comp   5  343.6180 68.72360 188.4690     0
Residuals 130   47.4034  0.36464
> tapply(tm1[,"Avg"],tm1[,"Comp"],mean)
      CC2      CF2      PA2      QA2      RM2      RS2
 3.659967 3.597181 3.922172 3.812685 3.350434 3.631256
> boxplot(split(tm1[,"Avg"],tm1[,"Squad"]))

> aovn1_anova(aov(Avg~Squad+Comp, data = tm1, weights=tmn1$weights))
> aovn1_anova(aov(Avg~Squad+Comp, data = tmn1, weights=tmn1$weights))
> aovn2_aov(Avg~Squad+Comp, data = tmn1, weights=tmn1$weights)
> mult1n_multicomp(aovn2, focus = "Comp", method="tukey", plot=T)
> mult1n

95 % simultaneous confidence intervals for specified
linear combinations, by the Tukey method

critical point: 2.8927
response variable: Avg

intervals excluding 0 are flagged by '****'

        Estimate Std.Error Lower Bound Upper Bound
CC2-CF2   0.0794    0.0202      0.0209      0.1380 ****
CC2-PA2  -0.2620    0.0202     -0.3200     -0.2030 ****
CC2-QA2  -0.1330    0.0202     -0.1910     -0.0741 ****
CC2-RM2   0.3150    0.0202      0.2560      0.3730 ****
CC2-RS2   0.0399    0.0202     -0.0186      0.0985
CF2-PA2  -0.3410    0.0202     -0.4000     -0.2830 ****
CF2-QA2  -0.2120    0.0202     -0.2700     -0.1530 ****
CF2-RM2   0.2350    0.0202      0.1770      0.2940 ****
CF2-RS2  -0.0394    0.0202     -0.0979      0.0191
PA2-QA2   0.1290    0.0202      0.0706      0.1880 ****
PA2-RM2   0.5770    0.0202      0.5180      0.6350 ****
PA2-RS2   0.3020    0.0202      0.2430      0.3600 ****
QA2-RM2   0.4470    0.0202      0.3890      0.5060 ****
QA2-RS2   0.1730    0.0202      0.1140      0.2310 ****
RM2-RS2  -0.2750    0.0202     -0.3330     -0.2160 ****

> aovn1
Analysis of Variance Table

Response: Avg

Terms added sequentially (first to last)
          Df Sum of Sq  Mean Sq  F Value Pr(F)
    Squad  26  405.3787 15.59149  42.7584     0
     Comp   5  343.6180 68.72360 188.4690     0
Residuals 130   47.4034  0.36464
> summary(aovn1)
        Df           Sum of Sq        Mean Sq           F Value          Pr(F)
    Min.:  5.00      Min.: 47.4      Min.: 0.3646      Min.: 42.76      Min.:0
 1st Qu.: 15.50   1st Qu.:195.5   1st Qu.: 7.9780   1st Qu.: 79.19   1st Qu.:0
```

```
  Median: 26.00    Median:343.6    Median:15.5900    Median:115.60    Median:0
    Mean: 53.67      Mean:265.5      Mean:28.2300      Mean:115.60      Mean:0
 3rd Qu.: 78.00   3rd Qu.:374.5   3rd Qu.:42.1600   3rd Qu.:152.00   3rd Qu.:0
    Max.:130.00      Max.:405.4      Max.:68.7200      Max.:188.50      Max.:0
                                                      NA's:  1.00      NA's:1
> aovn2
Call:
   aov(formula = Avg ~ Squad + Comp, data = tmn1, weights = tmn1$weights)

Terms:
                   Squad     Comp Residuals
 Sum of Squares 405.3787 343.6180    0.8796
Deg. of Freedom       26        5       130

Residual standard error: 0.08225805
Estimated effects may be unbalanced
> summary(aovn2)
           Df Sum of Sq  Mean Sq  F Value Pr(F)
    Squad  26  405.3787 15.59149  42.7584     0
     Comp   5  343.6180 68.72360 188.4690     0
Residuals 130   47.4034  0.36464
>
mult2_multicomp(aovn2, focus = "Squad", method="tukey", plot = T)
> mult2

95 % simultaneous confidence intervals for specified
linear combinations, by the Tukey method

critical point: 3.7796
response variable: Avg

intervals excluding 0 are flagged by '****'

       Estimate Std.Error Lower Bound Upper Bound
 1-10  0.575000    0.0441    0.408000     0.74100 ****
 1-11  0.508000    0.0628    0.271000     0.74500 ****
 1-12  0.752000    0.0415    0.595000     0.90800 ****
 1-13  0.733000    0.0444    0.565000     0.90100 ****
 1-14  0.446000    0.0410    0.291000     0.60100 ****
 1-15  0.429000    0.0362    0.292000     0.56600 ****
 1-16  0.900000    0.0582    0.680000     1.12000 ****
 1-17  0.865000    0.0403    0.712000     1.02000 ****
 1-18  0.500000    0.0487    0.316000     0.68400 ****
 1-19  0.330000    0.0503    0.140000     0.52100 ****
  1-2  0.310000    0.0411    0.155000     0.46500 ****
 1-20  0.647000    0.0456    0.475000     0.81900 ****
 1-21  0.829000    0.0574    0.612000     1.05000 ****
 1-22  0.400000    0.0432    0.237000     0.56300 ****
 1-23  0.548000    0.0402    0.397000     0.70000 ****
 1-24  0.419000    0.0421    0.260000     0.57800 ****
 1-25  0.468000    0.0548    0.261000     0.67600 ****
 1-26  0.347000    0.0598    0.121000     0.57300 ****
 1-27  0.163000    0.0598   -0.063200     0.38900
  1-3  0.410000    0.0484    0.227000     0.59200 ****
  1-4  0.902000    0.0554    0.693000     1.11000 ****
  1-5  0.461000    0.0450    0.291000     0.63100 ****
  1-6  0.598000    0.0478    0.417000     0.77800 ****
  1-7  0.412000    0.0410    0.257000     0.56700 ****
  1-8  0.699000    0.0413    0.543000     0.85600 ****
  1-9  0.399000    0.0561    0.187000     0.61100 ****
10-11 -0.066400    0.0615   -0.299000     0.16600
10-12  0.177000    0.0396    0.027200     0.32700 ****
10-13  0.159000    0.0426   -0.002430     0.32000
10-14 -0.129000    0.0391   -0.276000     0.01890
10-15 -0.146000    0.0340   -0.274000    -0.01740 ****
10-16  0.325000    0.0568    0.110000     0.54000 ****
10-17  0.290000    0.0383    0.145000     0.43500 ****
10-18 -0.075100    0.0471   -0.253000     0.10300
10-19 -0.244000    0.0487   -0.428000    -0.06000 ****
 10-2 -0.265000    0.0392   -0.413000    -0.11700 ****
10-20  0.072200    0.0439   -0.093500     0.23800
```

10-21	0.255000	0.0561	0.042800	0.46700	****
10-22	-0.175000	0.0414	-0.331000	-0.01820	****
10-23	-0.026100	0.0382	-0.171000	0.11800	
10-24	-0.155000	0.0402	-0.307000	-0.00339	****
10-25	-0.106000	0.0534	-0.308000	0.09580	
10-26	-0.227000	0.0585	-0.449000	-0.00627	****
10-27	-0.412000	0.0585	-0.633000	-0.19000	****
10-3	-0.165000	0.0468	-0.342000	0.01160	
10-4	0.327000	0.0540	0.123000	0.53200	****
10-5	-0.113000	0.0433	-0.277000	0.05010	
10-6	0.023000	0.0462	-0.152000	0.19800	
10-7	-0.163000	0.0391	-0.311000	-0.01510	****
10-8	0.125000	0.0394	-0.024100	0.27400	
10-9	-0.175000	0.0547	-0.382000	0.03130	
11-12	0.243000	0.0597	0.017600	0.46900	****
11-13	0.225000	0.0618	-0.008430	0.45800	
11-14	-0.062300	0.0594	-0.287000	0.16200	
11-15	-0.079300	0.0562	-0.292000	0.13300	
11-16	0.391000	0.0723	0.118000	0.66500	****
11-17	0.356000	0.0589	0.134000	0.57900	****
11-18	-0.008620	0.0649	-0.254000	0.23700	
11-19	-0.178000	0.0662	-0.428000	0.07230	
11-2	-0.198000	0.0594	-0.423000	0.02630	
11-20	0.139000	0.0626	-0.098100	0.37500	
11-21	0.321000	0.0717	0.050100	0.59200	****
11-22	-0.108000	0.0610	-0.339000	0.12200	
11-23	0.040300	0.0588	-0.182000	0.26300	
11-24	-0.088900	0.0601	-0.316000	0.13800	
11-25	-0.039700	0.0697	-0.303000	0.22400	
11-26	-0.161000	0.0737	-0.439000	0.11700	
11-27	-0.345000	0.0737	-0.624000	-0.06680	****
11-3	-0.098700	0.0647	-0.343000	0.14600	
11-4	0.394000	0.0701	0.129000	0.65900	****
11-5	-0.047100	0.0622	-0.282000	0.18800	
11-6	0.089500	0.0643	-0.154000	0.33200	
11-7	-0.096400	0.0594	-0.321000	0.12800	
11-8	0.191000	0.0596	-0.034000	0.41700	
11-9	-0.109000	0.0706	-0.376000	0.15800	
12-13	-0.018400	0.0400	-0.169000	0.13300	
12-14	-0.306000	0.0362	-0.442000	-0.16900	****
12-15	-0.323000	0.0306	-0.438000	-0.20700	****
12-16	0.148000	0.0549	-0.059400	0.35600	
12-17	0.113000	0.0353	-0.020500	0.24700	
12-18	-0.252000	0.0447	-0.421000	-0.08310	****
12-19	-0.421000	0.0464	-0.597000	-0.24600	****
12-2	-0.442000	0.0363	-0.579000	-0.30500	****
12-20	-0.105000	0.0413	-0.261000	0.05140	
12-21	0.077800	0.0541	-0.127000	0.28200	
12-22	-0.352000	0.0387	-0.498000	-0.20500	****
12-23	-0.203000	0.0353	-0.336000	-0.06980	****
12-24	-0.332000	0.0374	-0.474000	-0.19100	****
12-25	-0.283000	0.0513	-0.477000	-0.08900	****
12-26	-0.404000	0.0566	-0.618000	-0.19000	****
12-27	-0.589000	0.0566	-0.803000	-0.37500	****
12-3	-0.342000	0.0444	-0.510000	-0.17400	****
12-4	0.151000	0.0520	-0.045900	0.34700	
12-5	-0.290000	0.0407	-0.444000	-0.13700	****
12-6	-0.154000	0.0438	-0.319000	0.01150	
12-7	-0.340000	0.0362	-0.476000	-0.20300	****
12-8	-0.052100	0.0365	-0.190000	0.08610	
12-9	-0.352000	0.0526	-0.551000	-0.15300	****
13-14	-0.287000	0.0394	-0.436000	-0.13800	****
13-15	-0.304000	0.0344	-0.434000	-0.17400	****
13-16	0.166000	0.0571	-0.049300	0.38200	
13-17	0.131000	0.0387	-0.014600	0.27800	
13-18	-0.234000	0.0473	-0.413000	-0.05470	****
13-19	-0.403000	0.0490	-0.588000	-0.21800	****
13-2	-0.423000	0.0395	-0.573000	-0.27400	****
13-20	-0.086300	0.0442	-0.253000	0.08060	
13-21	0.096100	0.0563	-0.117000	0.30900	
13-22	-0.333000	0.0417	-0.491000	-0.17600	****

13-23	-0.185000	0.0386	-0.331000	-0.03890	****
13-24	-0.314000	0.0406	-0.467000	-0.16100	****
13-25	-0.265000	0.0537	-0.468000	-0.06180	****
13-26	-0.386000	0.0588	-0.608000	-0.16400	****
13-27	-0.570000	0.0588	-0.792000	-0.34800	****
13-3	-0.324000	0.0471	-0.502000	-0.14600	****
13-4	0.169000	0.0543	-0.036300	0.37400	
13-5	-0.272000	0.0436	-0.437000	-0.10700	****
13-6	-0.136000	0.0465	-0.311000	0.04020	
13-7	-0.321000	0.0394	-0.470000	-0.17200	****
13-8	-0.033700	0.0398	-0.184000	0.11700	
13-9	-0.334000	0.0549	-0.542000	-0.12600	****
14-15	-0.017000	0.0299	-0.130000	0.09600	
14-16	0.454000	0.0545	0.248000	0.66000	****
14-17	0.419000	0.0347	0.288000	0.55000	****
14-18	0.053700	0.0442	-0.113000	0.22100	
14-19	-0.115000	0.0460	-0.289000	0.05840	
14-2	-0.136000	0.0357	-0.271000	-0.00118	****
14-20	0.201000	0.0408	0.046900	0.35500	****
14-21	0.383000	0.0537	0.181000	0.58600	****
14-22	-0.045900	0.0381	-0.190000	0.09820	
14-23	0.103000	0.0347	-0.028300	0.23400	
14-24	-0.026600	0.0368	-0.166000	0.11300	
14-25	0.022600	0.0509	-0.170000	0.21500	
14-26	-0.098700	0.0563	-0.311000	0.11400	
14-27	-0.283000	0.0563	-0.496000	-0.07030	****
14-3	-0.036300	0.0439	-0.202000	0.13000	
14-4	0.456000	0.0516	0.261000	0.65100	****
14-5	0.015300	0.0402	-0.137000	0.16700	
14-6	0.152000	0.0433	-0.011800	0.31500	
14-7	-0.034000	0.0356	-0.169000	0.10000	
14-8	0.254000	0.0360	0.118000	0.39000	****
14-9	-0.046600	0.0522	-0.244000	0.15100	
15-16	0.471000	0.0510	0.278000	0.66300	****
15-17	0.436000	0.0289	0.327000	0.54500	****
15-18	0.070700	0.0398	-0.079600	0.22100	
15-19	-0.098500	0.0417	-0.256000	0.05930	
15-2	-0.119000	0.0300	-0.232000	-0.00571	****
15-20	0.218000	0.0359	0.082200	0.35400	****
15-21	0.400000	0.0501	0.211000	0.59000	****
15-22	-0.029000	0.0329	-0.153000	0.09530	
15-23	0.120000	0.0288	0.010900	0.22800	****
15-24	-0.009650	0.0314	-0.128000	0.10900	
15-25	0.039600	0.0471	-0.139000	0.21800	
15-26	-0.081800	0.0528	-0.281000	0.11800	
15-27	-0.266000	0.0528	-0.466000	-0.06620	****
15-3	-0.019400	0.0394	-0.168000	0.13000	
15-4	0.473000	0.0478	0.292000	0.65400	****
15-5	0.032200	0.0352	-0.101000	0.16500	
15-6	0.169000	0.0387	0.022400	0.31500	****
15-7	-0.017100	0.0299	-0.130000	0.09580	
15-8	0.271000	0.0303	0.156000	0.38500	****
15-9	-0.029600	0.0485	-0.213000	0.15400	
16-17	-0.035000	0.0540	-0.239000	0.16900	
16-18	-0.400000	0.0605	-0.629000	-0.17100	****
16-19	-0.569000	0.0618	-0.803000	-0.33600	****
16-2	-0.590000	0.0546	-0.796000	-0.38400	****
16-20	-0.253000	0.0580	-0.472000	-0.03350	****
16-21	-0.070300	0.0677	-0.326000	0.18600	
16-22	-0.500000	0.0562	-0.712000	-0.28700	****
16-23	-0.351000	0.0539	-0.555000	-0.14700	****
16-24	-0.480000	0.0553	-0.690000	-0.27100	****
16-25	-0.431000	0.0656	-0.679000	-0.18300	****
16-26	-0.553000	0.0698	-0.816000	-0.28900	****
16-27	-0.737000	0.0698	-1.000000	-0.47300	****
16-3	-0.490000	0.0603	-0.718000	-0.26200	****
16-4	0.002400	0.0661	-0.247000	0.25200	
16-5	-0.439000	0.0576	-0.656000	-0.22100	****
16-6	-0.302000	0.0598	-0.528000	-0.07590	****
16-7	-0.488000	0.0545	-0.694000	-0.28200	****
16-8	-0.200000	0.0548	-0.407000	0.00679	

16-9	-0.500000	0.0666	-0.752000	-0.24900	****
17-18	-0.365000	0.0435	-0.530000	-0.20100	****
17-19	-0.534000	0.0453	-0.706000	-0.36300	****
17-2	-0.555000	0.0348	-0.686000	-0.42300	****
17-20	-0.218000	0.0400	-0.369000	-0.06640	****
17-21	-0.035300	0.0531	-0.236000	0.16600	
17-22	-0.465000	0.0373	-0.606000	-0.32400	****
17-23	-0.316000	0.0338	-0.444000	-0.18800	****
17-24	-0.445000	0.0360	-0.582000	-0.30900	****
17-25	-0.396000	0.0503	-0.586000	-0.20600	****
17-26	-0.518000	0.0557	-0.728000	-0.30700	****
17-27	-0.702000	0.0557	-0.912000	-0.49100	****
17-3	-0.455000	0.0432	-0.618000	-0.29200	****
17-4	0.037400	0.0510	-0.155000	0.23000	
17-5	-0.404000	0.0394	-0.552000	-0.25500	****
17-6	-0.267000	0.0426	-0.428000	-0.10600	****
17-7	-0.453000	0.0347	-0.584000	-0.32200	****
17-8	-0.165000	0.0351	-0.298000	-0.03240	****
17-9	-0.465000	0.0517	-0.661000	-0.27000	****
18-19	-0.169000	0.0529	-0.369000	0.03100	
18-2	-0.190000	0.0443	-0.357000	-0.02240	****
18-20	0.147000	0.0485	-0.036000	0.33100	
18-21	0.330000	0.0598	0.104000	0.55600	****
18-22	-0.099600	0.0463	-0.275000	0.07530	
18-23	0.048900	0.0435	-0.115000	0.21300	
18-24	-0.080300	0.0452	-0.251000	0.09060	
18-25	-0.031100	0.0573	-0.248000	0.18500	
18-26	-0.152000	0.0621	-0.387000	0.08220	
18-27	-0.337000	0.0621	-0.571000	-0.10200	****
18-3	-0.090000	0.0511	-0.283000	0.10300	
18-4	0.403000	0.0579	0.184000	0.62100	****
18-5	-0.038400	0.0480	-0.220000	0.14300	
18-6	0.098100	0.0506	-0.093200	0.28900	
18-7	-0.087700	0.0442	-0.255000	0.07930	
18-8	0.200000	0.0445	0.031700	0.36800	****
18-9	-0.100000	0.0585	-0.321000	0.12100	
19-2	-0.020600	0.0461	-0.195000	0.15400	
19-20	0.316000	0.0501	0.127000	0.50600	****
19-21	0.499000	0.0611	0.268000	0.73000	****
19-22	0.069500	0.0480	-0.112000	0.25100	
19-23	0.218000	0.0453	0.046900	0.38900	****
19-24	0.088800	0.0470	-0.088700	0.26600	
19-25	0.138000	0.0587	-0.083700	0.36000	
19-26	0.016700	0.0634	-0.223000	0.25600	
19-27	-0.167000	0.0634	-0.407000	0.07200	
19-3	0.079100	0.0527	-0.120000	0.27800	
19-4	0.572000	0.0592	0.348000	0.79600	****
19-5	0.131000	0.0496	-0.056800	0.31800	
19-6	0.267000	0.0522	0.070000	0.46400	****
19-7	0.081400	0.0460	-0.092400	0.25500	
19-8	0.369000	0.0463	0.194000	0.54400	****
19-9	0.068900	0.0598	-0.157000	0.29500	
2-20	0.337000	0.0409	0.183000	0.49100	****
2-21	0.520000	0.0538	0.316000	0.72300	****
2-22	0.090100	0.0382	-0.054400	0.23500	
2-23	0.239000	0.0348	0.107000	0.37000	****
2-24	0.109000	0.0369	-0.030100	0.24900	
2-25	0.159000	0.0510	-0.034100	0.35100	
2-26	0.037300	0.0563	-0.176000	0.25000	
2-27	-0.147000	0.0563	-0.360000	0.06600	
2-3	0.099700	0.0440	-0.066500	0.26600	
2-4	0.592000	0.0516	0.397000	0.78700	****
2-5	0.151000	0.0402	-0.000825	0.30300	
2-6	0.288000	0.0434	0.124000	0.45200	****
2-7	0.102000	0.0357	-0.032900	0.23700	
2-8	0.390000	0.0361	0.253000	0.52600	****
2-9	0.089400	0.0523	-0.108000	0.28700	
20-21	0.182000	0.0573	-0.034000	0.39900	
20-22	-0.247000	0.0430	-0.410000	-0.08430	****
20-23	-0.098400	0.0400	-0.249000	0.05270	
20-24	-0.228000	0.0419	-0.386000	-0.06930	****

20-25	-0.178000	0.0547	-0.385000	0.02830	
20-26	-0.300000	0.0597	-0.525000	-0.07410	****
20-27	-0.484000	0.0597	-0.710000	-0.25800	****
20-3	-0.237000	0.0482	-0.420000	-0.05520	****
20-4	0.255000	0.0553	0.046300	0.46400	****
20-5	-0.186000	0.0448	-0.355000	-0.01630	****
20-6	-0.049200	0.0476	-0.229000	0.13100	
20-7	-0.235000	0.0408	-0.389000	-0.08090	****
20-8	0.052600	0.0411	-0.103000	0.20800	
20-9	-0.248000	0.0559	-0.459000	-0.03630	****
21-22	-0.429000	0.0554	-0.639000	-0.22000	****
21-23	-0.281000	0.0531	-0.482000	-0.08020	****
21-24	-0.410000	0.0545	-0.616000	-0.20400	****
21-25	-0.361000	0.0649	-0.606000	-0.11600	****
21-26	-0.482000	0.0692	-0.744000	-0.22100	****
21-27	-0.666000	0.0692	-0.928000	-0.40500	****
21-3	-0.420000	0.0595	-0.645000	-0.19500	****
21-4	0.072700	0.0654	-0.174000	0.32000	
21-5	-0.368000	0.0568	-0.583000	-0.15300	****
21-6	-0.232000	0.0591	-0.455000	-0.00838	****
21-7	-0.418000	0.0537	-0.621000	-0.21500	****
21-8	-0.130000	0.0540	-0.334000	0.07410	
21-9	-0.430000	0.0659	-0.679000	-0.18100	****
22-23	0.149000	0.0373	0.007690	0.28900	****
22-24	0.019300	0.0393	-0.129000	0.16800	
22-25	0.068600	0.0527	-0.131000	0.26800	
22-26	-0.052800	0.0579	-0.272000	0.16600	
22-27	-0.237000	0.0579	-0.456000	-0.01810	****
22-3	0.009610	0.0460	-0.164000	0.18300	
22-4	0.502000	0.0534	0.300000	0.70400	****
22-5	0.061200	0.0424	-0.099200	0.22200	
22-6	0.198000	0.0454	0.026100	0.36900	****
22-7	0.011900	0.0381	-0.132000	0.15600	
22-8	0.300000	0.0385	0.154000	0.44500	****
22-9	-0.000643	0.0540	-0.205000	0.20300	
23-24	-0.129000	0.0359	-0.265000	0.00658	
23-25	-0.080000	0.0503	-0.270000	0.11000	
23-26	-0.201000	0.0557	-0.412000	0.00909	
23-27	-0.386000	0.0557	-0.596000	-0.17500	****
23-3	-0.139000	0.0431	-0.302000	0.02410	
23-4	0.354000	0.0509	0.161000	0.54600	****
23-5	-0.087400	0.0393	-0.236000	0.06140	
23-6	0.049200	0.0425	-0.112000	0.21000	
23-7	-0.137000	0.0347	-0.268000	-0.00569	****
23-8	0.151000	0.0351	0.018500	0.28300	****
23-9	-0.149000	0.0516	-0.344000	0.04590	
24-25	0.049200	0.0518	-0.147000	0.24500	
24-26	-0.072100	0.0571	-0.288000	0.14400	
24-27	-0.256000	0.0571	-0.472000	-0.04060	****
24-3	-0.009720	0.0449	-0.179000	0.16000	
24-4	0.483000	0.0524	0.285000	0.68100	****
24-5	0.041900	0.0413	-0.114000	0.19800	
24-6	0.178000	0.0443	0.010900	0.34600	****
24-7	-0.007430	0.0368	-0.147000	0.13200	
24-8	0.280000	0.0372	0.140000	0.42100	****
24-9	-0.020000	0.0531	-0.221000	0.18100	
25-26	-0.121000	0.0670	-0.375000	0.13200	
25-27	-0.306000	0.0670	-0.559000	-0.05220	****
25-3	-0.058900	0.0570	-0.275000	0.15700	
25-4	0.434000	0.0631	0.195000	0.67200	****
25-5	-0.007350	0.0542	-0.212000	0.19800	
25-6	0.129000	0.0566	-0.084700	0.34300	
25-7	-0.056700	0.0509	-0.249000	0.13600	
25-8	0.231000	0.0512	0.037500	0.42500	****
25-9	-0.069200	0.0637	-0.310000	0.17200	
26-27	-0.184000	0.0712	-0.453000	0.08480	
26-3	0.062400	0.0618	-0.171000	0.29600	
26-4	0.555000	0.0675	0.300000	0.81000	****
26-5	0.114000	0.0593	-0.110000	0.33800	
26-6	0.251000	0.0614	0.018400	0.48300	****
26-7	0.064700	0.0563	-0.148000	0.27700	

26-8	0.352000	0.0565	0.139000	0.56600	****
26-9	0.052100	0.0680	-0.205000	0.30900	
27-3	0.247000	0.0618	0.012800	0.48000	****
27-4	0.739000	0.0675	0.484000	0.99400	****
27-5	0.298000	0.0593	0.074200	0.52200	****
27-6	0.435000	0.0614	0.203000	0.66700	****
27-7	0.249000	0.0563	0.036200	0.46200	****
27-8	0.537000	0.0565	0.323000	0.75000	****
27-9	0.236000	0.0680	-0.020800	0.49300	
3-4	0.493000	0.0576	0.275000	0.71000	****
3-5	0.051600	0.0477	-0.129000	0.23200	
3-6	0.188000	0.0503	-0.002120	0.37800	
3-7	0.002280	0.0439	-0.164000	0.16800	
3-8	0.290000	0.0442	0.123000	0.45700	****
3-9	-0.010300	0.0582	-0.230000	0.21000	
4-5	-0.441000	0.0548	-0.648000	-0.23400	****
4-6	-0.304000	0.0571	-0.520000	-0.08840	****
4-7	-0.490000	0.0516	-0.685000	-0.29500	****
4-8	-0.203000	0.0518	-0.398000	-0.00667	****
4-9	-0.503000	0.0642	-0.745000	-0.26000	****
5-6	0.137000	0.0471	-0.041600	0.31500	
5-7	-0.049300	0.0402	-0.201000	0.10200	
5-8	0.238000	0.0405	0.085300	0.39100	****
5-9	-0.061900	0.0555	-0.271000	0.14800	
6-7	-0.186000	0.0433	-0.349000	-0.02220	****
6-8	0.102000	0.0436	-0.062900	0.26700	
6-9	-0.198000	0.0578	-0.417000	0.01990	
7-8	0.288000	0.0360	0.152000	0.42400	****
7-9	-0.012500	0.0522	-0.210000	0.18500	
8-9	-0.300000	0.0525	-0.499000	-0.10200	****

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APPENDIX E. REGRESSION DATA

```
*** Linear Model ***

Call: lm(formula = IR ~ Av2, data = SquadDem2, weights = N, na.action =
na.exclude)
Residuals:
    Min   1Q Median    3Q  Max
 -874.1 -472 -283.7 63.26 6300

Coefficients:
                Value Std. Error   t value  Pr(>|t|)
(Intercept)  286.2731  618.7363     0.4627    0.6476
        Av2  -61.3768  169.5128    -0.3621    0.7203

Residual standard error: 1387 on 25 degrees of freedom
Multiple R-Squared: 0.005217
F-statistic: 0.1311 on 1 and 25 degrees of freedom, the p-value is
0.7203

Analysis of Variance Table

Response: IR

Terms added sequentially (first to last)
           Df Sum of Sq Mean Sq   F Value     Pr(F)
      Av2   1    252033  252033 0.1311004 0.7203365
 Residuals 25  48061082 1922443


*** Linear Model ***

Call: lm(formula = IR ~ Avg, data = IRno900, na.action = na.exclude)
Residuals:
    Min     1Q Median    3Q   Max
 -55.34 -45.41 -19.68 12.99 251.2

Coefficients:
                Value Std. Error   t value  Pr(>|t|)
(Intercept)  125.5060  230.7976     0.5438    0.5914
        Avg  -21.4207   63.2853    -0.3385    0.7378

Residual standard error: 70.45 on 25 degrees of freedom
Multiple R-Squared: 0.004562
F-statistic: 0.1146 on 1 and 25 degrees of freedom, the p-value is 0.7378

Analysis of Variance Table

Response: IR

Terms added sequentially (first to last)
          Df Sum of Sq  Mean Sq   F Value     Pr(F)
      Avg  1     568.6  568.621 0.1145679 0.7378286
Residuals 25  124079.3 4963.174
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APPENDIX F. SIMPLE AND REDUCED MODELS

```
PA2.lm_lm(PA2~Rank2+WC2+Status+YrsExp+Shift+AC, data=ahindivid, na.action=na.exclude)
> summary(PA2.lm)
Call: lm(formula = PA2 ~ Rank2 + WC2 + Status + YrsExp + Shift + AC, data = ahindivid,
na.action = na.exclude)
Residuals:
    Min      1Q  Median     3Q   Max
 -3.012 -0.2831 0.06063 0.3906 1.351
Coefficients:
                          Value Std. Error  t value Pr(>|t|)
           (Intercept)   3.9430   0.0899    43.8445   0.0000
              Rank2E47  -0.0771   0.0509    -1.5137   0.1303
              Rank2E89   0.1768   0.1162     1.5205   0.1286
              Rank2Ofc   0.2026   0.0978     2.0714   0.0385
           WC2Avionics  -0.0557   0.0525    -1.0599   0.2893
        WC2Flight Line   0.0557   0.0581     0.9576   0.3384
              WC2Other   0.0274   0.0462     0.5926   0.5535
       WC2Power Plants  -0.0305   0.0673    -0.4526   0.6509
StatusDrilling Reserve   0.0613   0.0780     0.7855   0.4322
         StatusRegular   0.0665   0.0497     1.3377   0.1812
          YrsExp15-Nov   0.0794   0.0572     1.3879   0.1653
           YrsExp16-20   0.0830   0.0592     1.4021   0.1611
           YrsExp2-Jan   0.0946   0.0600     1.5768   0.1150
             YrsExp20+   0.0276   0.1085     0.2544   0.7992
           YrsExp5-Mar  -0.0205   0.0515    -0.3976   0.6909
              YrsExp<1   0.1747   0.0711     2.4576   0.0141
                 Shift  -0.0931   0.0353    -2.6401   0.0084
              ACNonTac  -0.0372   0.0435    -0.8540   0.3932
            ACTactical  -0.1348   0.0354    -3.8097   0.0001

Residual standard error: 0.6088 on 1702 degrees of freedom
Multiple R-Squared: 0.05105
F-statistic: 5.086 on 18 and 1702 degrees of freedom, the p-value is 1.708e-011
10 observations deleted due to missing values

> PA2.lm.stepAIC_stepAIC(PA2.lm, trace=F)
> summary(PA2.lm.stepAIC)
Call: lm(formula = PA2 ~ Rank2 + YrsExp + Shift + AC, data = ahindivid, na.action =
na.exclude)
Residuals:
    Min      1Q  Median     3Q   Max
 -2.978 -0.2863 0.04703 0.3814 1.303

Coefficients:
                Value Std. Error  t value Pr(>|t|)
 (Intercept)   4.0074   0.0688    58.2105   0.0000
    Rank2E47  -0.0829   0.0503    -1.6494   0.0993
    Rank2E89   0.1792   0.1156     1.5503   0.1212
    Rank2Ofc   0.2086   0.0967     2.1579   0.0311
YrsExp15-Nov   0.0883   0.0568     1.5536   0.1205
 YrsExp16-20   0.0998   0.0585     1.7057   0.0882
 YrsExp2-Jan   0.1072   0.0597     1.7937   0.0730
   YrsExp20+   0.0505   0.1079     0.4686   0.6394
 YrsExp5-Mar  -0.0164   0.0514    -0.3197   0.7492
    YrsExp<1   0.1979   0.0705     2.8062   0.0051
       Shift  -0.0940   0.0348    -2.7007   0.0070
    ACNonTac  -0.0598   0.0394    -1.5161   0.1297
  ACTactical  -0.1334   0.0352    -3.7939   0.0002

Residual standard error: 0.6091 on 1708 degrees of freedom
Multiple R-Squared: 0.04694
F-statistic: 7.01 on 12 and 1708 degrees of freedom, the p-value is 1.466e-012
10 observations deleted due to missing values
```

```
> RS2.lm_lm(RS2~Rank2+WC2+Status+YrsExp+Shift+AC, data=ahindivid, na.action=na.exclude)
> summary(RS2.lm)
Call: lm(formula = RS2 ~ Rank2 + WC2 + Status + YrsExp + Shift + AC, data = ahindivid,
na.action = na.exclude)
Residuals:
   Min      1Q  Median     3Q   Max
 -2.82 -0.3505 0.04489 0.4426 1.554

Coefficients:
                          Value Std. Error  t value Pr(>|t|)
           (Intercept)   3.6729   0.0957    38.3908   0.0000
              Rank2E47  -0.1201   0.0541    -2.2199   0.0266
              Rank2E89   0.2337   0.1238     1.8876   0.0592
              Rank2Ofc   0.3579   0.1042     3.4358   0.0006
           WC2Avionics  -0.0181   0.0559    -0.3247   0.7454
        WC2Flight Line   0.1180   0.0619     1.9057   0.0569
              WC2Other   0.0298   0.0492     0.6054   0.5450
       WC2Power Plants   0.0592   0.0718     0.8247   0.4097
StatusDrilling Reserve   0.1406   0.0824     1.7068   0.0880
         StatusRegular   0.0101   0.0529     0.1901   0.8492
          YrsExp15-Nov   0.0849   0.0608     1.3966   0.1627
           YrsExp16-20   0.0845   0.0629     1.3423   0.1797
           YrsExp2-Jan   0.0892   0.0638     1.3976   0.1624
             YrsExp20+  -0.0718   0.1155    -0.6212   0.5346
           YrsExp5-Mar  -0.0750   0.0546    -1.3731   0.1699
              YrsExp<1   0.3219   0.0753     4.2727   0.0000
                 Shift  -0.0809   0.0375    -2.1572   0.0311
              ACNonTac   0.0310   0.0463     0.6703   0.5028
            ACTactical  -0.1488   0.0377    -3.9483   0.0001

Residual standard error: 0.6487 on 1709 degrees of freedom
Multiple R-Squared: 0.09315
F-statistic: 9.753 on 18 and 1709 degrees of freedom, the p-value is 0
3 observations deleted due to missing values

> RS2.lm.stepAIC_stepAIC(RS2.lm, trace=F)
> summary(RS2.lm.stepAIC)

Call: lm(formula = RS2 ~ Rank2 + YrsExp + Shift + AC, data = ahindivid, na.action =
na.exclude)
Residuals:
    Min      1Q  Median     3Q   Max
 -2.864 -0.3452 0.05439 0.4415 1.558

Coefficients:
                Value Std. Error  t value Pr(>|t|)
 (Intercept)   3.7261   0.0732    50.8970   0.0000
    Rank2E47  -0.1359   0.0535    -2.5414   0.0111
    Rank2E89   0.2097   0.1232     1.7024   0.0889
    Rank2Ofc   0.3395   0.1030     3.2959   0.0010
YrsExp15-Nov   0.0910   0.0604     1.5056   0.1324
 YrsExp16-20   0.0938   0.0623     1.5061   0.1322
 YrsExp2-Jan   0.0945   0.0635     1.4874   0.1371
   YrsExp20+  -0.0501   0.1149    -0.4357   0.6631
 YrsExp5-Mar  -0.0725   0.0546    -1.3282   0.1843
    YrsExp<1   0.3402   0.0748     4.5477   0.0000
       Shift  -0.0909   0.0370    -2.4546   0.0142
    ACNonTac   0.0390   0.0420     0.9284   0.3533
  ACTactical  -0.1518   0.0375    -4.0518   0.0001

Residual standard error: 0.6493 on 1715 degrees of freedom
Multiple R-Squared: 0.08824
F-statistic: 13.83 on 12 and 1715 degrees of freedom, the p-value is 0
3 observations deleted due to missing values
```

```
> QA2.lm_lm(QA2~Rank2+WC2+Status+YrsExp+Shift+AC, data=ahindivid, na.action=na.exclude)
> summary(QA2.lm)

Call: lm(formula = QA2 ~ Rank2 + WC2 + Status + YrsExp + Shift + AC, data = ahindivid,
na.action = na.exclude)
Residuals:
    Min      1Q  Median     3Q   Max
 -3.006 -0.3789 0.05933 0.4407 1.472

Coefficients:
                          Value Std. Error  t value Pr(>|t|)
           (Intercept)   3.7862   0.0994    38.0921   0.0000
              Rank2E47  -0.1446   0.0562    -2.5717   0.0102
              Rank2E89   0.1165   0.1283     0.9082   0.3639
              Rank2Ofc   0.1763   0.1068     1.6503   0.0991
           WC2Avionics  -0.0405   0.0580    -0.6984   0.4850
        WC2Flight Line   0.0859   0.0642     1.3389   0.1808
              WC2Other   0.0942   0.0511     1.8453   0.0652
       WC2Power Plants   0.1041   0.0744     1.3998   0.1618
StatusDrilling Reserve   0.2073   0.0857     2.4179   0.0157
         StatusRegular   0.0083   0.0549     0.1505   0.8804
          YrsExp15-Nov   0.1349   0.0632     2.1336   0.0330
           YrsExp16-20   0.1674   0.0655     2.5562   0.0107
           YrsExp2-Jan   0.1763   0.0663     2.6598   0.0079
             YrsExp20+   0.2006   0.1198     1.6743   0.0942
           YrsExp5-Mar   0.0290   0.0568     0.5111   0.6093
              YrsExp<1   0.3271   0.0785     4.1673   0.0000
                 Shift  -0.0790   0.0388    -2.0348   0.0420
              ACNonTac  -0.0024   0.0481    -0.0500   0.9601
            ACTactical  -0.1657   0.0391    -4.2407   0.0000

Residual standard error: 0.6723 on 1702 degrees of freedom
Multiple R-Squared: 0.08277
F-statistic: 8.532 on 18 and 1702 degrees of freedom, the p-value is 0
10 observations deleted due to missing values

> QA2.lm.stepAIC_stepAIC(QA2.lm, trace=F)
> summary(QA2.lm.stepAIC)

Call: lm(formula = QA2 ~ Rank2 + WC2 + Status + YrsExp + Shift + AC, data = ahindivid,
na.action = na.exclude)
Residuals:
    Min      1Q  Median     3Q   Max
 -3.006 -0.3789 0.05933 0.4407 1.472

Coefficients:
                          Value Std. Error  t value Pr(>|t|)
           (Intercept)   3.7862   0.0994    38.0921   0.0000
              Rank2E47  -0.1446   0.0562    -2.5717   0.0102
              Rank2E89   0.1165   0.1283     0.9082   0.3639
              Rank2Ofc   0.1763   0.1068     1.6503   0.0991
           WC2Avionics  -0.0405   0.0580    -0.6984   0.4850
        WC2Flight Line   0.0859   0.0642     1.3389   0.1808
              WC2Other   0.0942   0.0511     1.8453   0.0652
       WC2Power Plants   0.1041   0.0744     1.3998   0.1618
StatusDrilling Reserve   0.2073   0.0857     2.4179   0.0157
         StatusRegular   0.0083   0.0549     0.1505   0.8804
          YrsExp15-Nov   0.1349   0.0632     2.1336   0.0330
           YrsExp16-20   0.1674   0.0655     2.5562   0.0107
           YrsExp2-Jan   0.1763   0.0663     2.6598   0.0079
             YrsExp20+   0.2006   0.1198     1.6743   0.0942
           YrsExp5-Mar   0.0290   0.0568     0.5111   0.6093
              YrsExp<1   0.3271   0.0785     4.1673   0.0000
                 Shift  -0.0790   0.0388    -2.0348   0.0420
              ACNonTac  -0.0024   0.0481    -0.0500   0.9601
            ACTactical  -0.1657   0.0391    -4.2407   0.0000

Residual standard error: 0.6723 on 1702 degrees of freedom
```

```
Multiple R-Squared: 0.08277
F-statistic: 8.532 on 18 and 1702 degrees of freedom, the p-value is 0
10 observations deleted due to missing values
> RM2.lm_lm(RM2~Rank2+WC2+Status+YrsExp+Shift+AC, data=ahindivid, na.action=na.exclude)
summary(RM2.lm)

Call: lm(formula = RM2 ~ Rank2 + WC2 + Status + YrsExp + Shift + AC, data = ahindivid,
na.action = na.exclude)
Residuals:
   Min      1Q  Median     3Q   Max
 -2.55 -0.3505 0.04374 0.3884 1.696

Coefficients:
                          Value Std. Error  t value Pr(>|t|)
           (Intercept)   3.3977   0.0870    39.0387   0.0000
              Rank2E47  -0.1820   0.0492    -3.6982   0.0002
              Rank2E89   0.0035   0.1127     0.0311   0.9752
              Rank2Ofc  -0.0668   0.0939    -0.7121   0.4765
           WC2Avionics  -0.0435   0.0509    -0.8549   0.3927
        WC2Flight Line   0.0736   0.0564     1.3052   0.1920
              WC2Other  -0.0316   0.0448    -0.7044   0.4813
       WC2Power Plants   0.0699   0.0654     1.0697   0.2849
StatusDrilling Reserve   0.2024   0.0747     2.7096   0.0068
         StatusRegular   0.0744   0.0482     1.5456   0.1224
          YrsExp15-Nov   0.0521   0.0554     0.9403   0.3472
           YrsExp16-20   0.0214   0.0573     0.3742   0.7083
           YrsExp2-Jan   0.1310   0.0580     2.2584   0.0240
             YrsExp20+  -0.1295   0.1052    -1.2309   0.2185
           YrsExp5-Mar   0.0448   0.0498     0.9010   0.3677
              YrsExp<1   0.3831   0.0685     5.5963   0.0000
                 Shift  -0.1547   0.0341    -4.5341   0.0000
              ACNonTac   0.1019   0.0421     2.4197   0.0156
            ACTactical  -0.1130   0.0343    -3.2924   0.0010

Residual standard error: 0.591 on 1712 degrees of freedom
Multiple R-Squared: 0.117
F-statistic: 12.6 on 18 and 1712 degrees of freedom, the p-value is 0

> RM2.lm.stepAIC_stepAIC(RM2.lm, trace=F)
> summary(RM2.lm.stepAIC)

Call: lm(formula = RM2 ~ Rank2 + WC2 + Status + YrsExp + Shift + AC, data = ahindivid,
na.action = na.exclude)
Residuals:
   Min      1Q  Median     3Q   Max
 -2.55 -0.3505 0.04374 0.3884 1.696

Coefficients:
                          Value Std. Error  t value Pr(>|t|)
           (Intercept)   3.3977   0.0870    39.0387   0.0000
              Rank2E47  -0.1820   0.0492    -3.6982   0.0002
              Rank2E89   0.0035   0.1127     0.0311   0.9752
              Rank2Ofc  -0.0668   0.0939    -0.7121   0.4765
           WC2Avionics  -0.0435   0.0509    -0.8549   0.3927
        WC2Flight Line   0.0736   0.0564     1.3052   0.1920
              WC2Other  -0.0316   0.0448    -0.7044   0.4813
       WC2Power Plants   0.0699   0.0654     1.0697   0.2849
StatusDrilling Reserve   0.2024   0.0747     2.7096   0.0068
         StatusRegular   0.0744   0.0482     1.5456   0.1224
          YrsExp15-Nov   0.0521   0.0554     0.9403   0.3472
           YrsExp16-20   0.0214   0.0573     0.3742   0.7083
           YrsExp2-Jan   0.1310   0.0580     2.2584   0.0240
             YrsExp20+  -0.1295   0.1052    -1.2309   0.2185
           YrsExp5-Mar   0.0448   0.0498     0.9010   0.3677
              YrsExp<1   0.3831   0.0685     5.5963   0.0000
                 Shift  -0.1547   0.0341    -4.5341   0.0000
              ACNonTac   0.1019   0.0421     2.4197   0.0156
            ACTactical  -0.1130   0.0343    -3.2924   0.0010

Residual standard error: 0.591 on 1712 degrees of freedom
Multiple R-Squared: 0.117
```

```
F-statistic: 12.6 on 18 and 1712 degrees of freedom, the p-value is 0


> CC2.lm_lm(CC2~Rank2+WC2+Status+YrsExp+Shift+AC, data=ahindivid, na.action=na.exclude)
> summary(CC2.lm)

Call: lm(formula = CC2 ~ Rank2 + WC2 + Status + YrsExp + Shift + AC, data = ahindivid,
na.action = na.exclude)
Residuals:
    Min      1Q  Median     3Q   Max
 -3.078 -0.3259 0.08156 0.3769 1.727

Coefficients:
                          Value Std. Error  t value Pr(>|t|)
           (Intercept)   3.6136   0.0930    38.8633   0.0000
              Rank2E47  -0.1293   0.0525    -2.4597   0.0140
              Rank2E89   0.2204   0.1202     1.8326   0.0670
              Rank2Ofc   0.2199   0.1001     2.1955   0.0283
           WC2Avionics  -0.0392   0.0543    -0.7222   0.4703
        WC2Flight Line   0.0717   0.0602     1.1923   0.2333
              WC2Other   0.0525   0.0479     1.0975   0.2726
       WC2Power Plants   0.0351   0.0697     0.5029   0.6151
StatusDrilling Reserve   0.2109   0.0797     2.6464   0.0082
         StatusRegular   0.0862   0.0515     1.6753   0.0941
          YrsExp15-Nov   0.1019   0.0592     1.7203   0.0856
           YrsExp16-20   0.0242   0.0612     0.3962   0.6920
           YrsExp2-Jan   0.1405   0.0620     2.2652   0.0236
             YrsExp20+  -0.0530   0.1123    -0.4719   0.6371
           YrsExp5-Mar   0.0594   0.0532     1.1166   0.2643
              YrsExp<1   0.3835   0.0732     5.2428   0.0000
                 Shift  -0.0966   0.0364    -2.6518   0.0081
              ACNonTac   0.0711   0.0451     1.5761   0.1152
            ACTactical  -0.1723   0.0366    -4.7063   0.0000

Residual standard error: 0.6305 on 1708 degrees of freedom
Multiple R-Squared: 0.09352
F-statistic: 9.79 on 18 and 1708 degrees of freedom, the p-value is 0
4 observations deleted due to missing values

> CC2.lm.stepAIC_stepAIC(CC2.lm, trace=F)
> summary(CC2.lm.stepAIC)

Call: lm(formula = CC2 ~ Rank2 + Status + YrsExp + Shift + AC, data = ahindivid,
na.action = na.exclude)
Residuals:
    Min      1Q  Median     3Q   Max
 -3.057 -0.3336 0.07561 0.3825 1.659

Coefficients:
                          Value Std. Error  t value Pr(>|t|)
           (Intercept)   3.6467   0.0840    43.3994   0.0000
              Rank2E47  -0.1356   0.0519    -2.6141   0.0090
              Rank2E89   0.2223   0.1197     1.8576   0.0634
              Rank2Ofc   0.2288   0.0990     2.3114   0.0209
StatusDrilling Reserve   0.2025   0.0797     2.5426   0.0111
         StatusRegular   0.0796   0.0514     1.5486   0.1217
          YrsExp15-Nov   0.1137   0.0588     1.9322   0.0535
           YrsExp16-20   0.0410   0.0605     0.6777   0.4981
           YrsExp2-Jan   0.1463   0.0619     2.3630   0.0182
             YrsExp20+  -0.0315   0.1119    -0.2817   0.7782
           YrsExp5-Mar   0.0617   0.0532     1.1604   0.2461
              YrsExp<1   0.4007   0.0728     5.5068   0.0000
                 Shift  -0.1031   0.0363    -2.8357   0.0046
              ACNonTac   0.0654   0.0450     1.4531   0.1464
            ACTactical  -0.1698   0.0364    -4.6653   0.0000

Residual standard error: 0.6309 on 1712 degrees of freedom
Multiple R-Squared: 0.09034
F-statistic: 12.14 on 14 and 1712 degrees of freedom, the p-value is 0
4 observations deleted due to missing values
```

```
> CF2.lm_lm(CF2~Rank2+WC2+Status+YrsExp+Shift+AC, data=ahindivid, na.action=na.exclude)
> summary(CF2.lm)

Call: lm(formula = CF2 ~ Rank2 + WC2 + Status + YrsExp + Shift + AC, data = ahindivid,
na.action = na.exclude)
Residuals:
    Min      1Q  Median     3Q   Max
 -2.795 -0.3464 0.07876 0.4184 1.614

Coefficients:
                          Value Std. Error  t value Pr(>|t|)
           (Intercept)   3.6967   0.0972    38.0141   0.0000
              Rank2E47  -0.1437   0.0550    -2.6146   0.0090
              Rank2E89   0.0316   0.1258     0.2511   0.8018
              Rank2Ofc   0.1680   0.1047     1.6037   0.1090
           WC2Avionics  -0.0260   0.0568    -0.4573   0.6475
        WC2Flight Line   0.0917   0.0629     1.4572   0.1452
              WC2Other   0.0148   0.0501     0.2958   0.7674
       WC2Power Plants   0.1018   0.0729     1.3954   0.1631
StatusDrilling Reserve   0.2194   0.0841     2.6097   0.0091
         StatusRegular   0.0158   0.0538     0.2934   0.7693
          YrsExp15-Nov   0.0062   0.0619     0.0993   0.9209
           YrsExp16-20   0.0201   0.0640     0.3141   0.7535
           YrsExp2-Jan   0.0974   0.0649     1.5006   0.1336
             YrsExp20+   0.0132   0.1175     0.1120   0.9109
           YrsExp5-Mar  -0.0069   0.0556    -0.1234   0.9018
              YrsExp<1   0.3376   0.0765     4.4128   0.0000
                 Shift  -0.1436   0.0381    -3.7692   0.0002
              ACNonTac  -0.0063   0.0471    -0.1343   0.8932
            ACTactical  -0.2032   0.0383    -5.3069   0.0000

Residual standard error: 0.6595 on 1708 degrees of freedom
Multiple R-Squared: 0.09417
F-statistic: 9.864 on 18 and 1708 degrees of freedom, the p-value is 0
4 observations deleted due to missing values

> CF2.lm.stepAIC_stepAIC(CF2.lm, trace=F)
> summary(CF2.lm.stepAIC)

Call: lm(formula = CF2 ~ Rank2 + Status + YrsExp + Shift + AC, data = ahindivid,
na.action = na.exclude)
Residuals:
    Min      1Q  Median     3Q   Max
 -2.743 -0.3506 0.08261 0.4158 1.598

Coefficients:
                          Value Std. Error  t value Pr(>|t|)
           (Intercept)   3.7351   0.0879    42.4968   0.0000
              Rank2E47  -0.1588   0.0543    -2.9268   0.0035
              Rank2E89   0.0135   0.1252     0.1081   0.9139
              Rank2Ofc   0.1511   0.1035     1.4593   0.1447
StatusDrilling Reserve   0.2153   0.0840     2.5625   0.0105
         StatusRegular   0.0108   0.0537     0.2001   0.8415
          YrsExp15-Nov   0.0068   0.0616     0.1101   0.9124
           YrsExp16-20   0.0221   0.0633     0.3496   0.7267
           YrsExp2-Jan   0.1019   0.0647     1.5739   0.1157
             YrsExp20+   0.0174   0.1170     0.1488   0.8817
           YrsExp5-Mar  -0.0030   0.0556    -0.0534   0.9574
              YrsExp<1   0.3510   0.0761     4.6126   0.0000
                 Shift  -0.1469   0.0380    -3.8655   0.0001
              ACNonTac  -0.0142   0.0470    -0.3026   0.7622
            ACTactical  -0.2075   0.0381    -5.4524   0.0000

Residual standard error: 0.6599 on 1712 degrees of freedom
Multiple R-Squared: 0.09096
F-statistic: 12.24 on 14 and 1712 degrees of freedom, the p-value is 0
4 observations deleted due to missing values
```

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